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MARCH

1911

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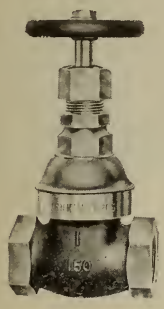

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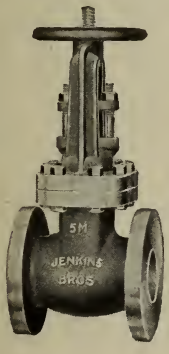

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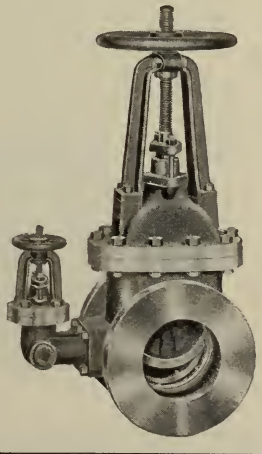

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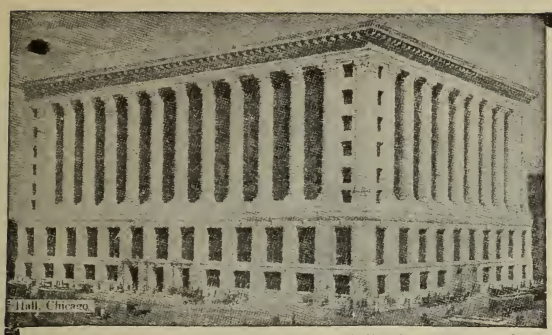

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VOL. XIX. MARCH No. 3

THE NEW ENGINEERING BUILDINGS

*Francis C. Shenehon**

The state legislature of 1907 passed what is known as the Campus Act. This act was intended to provide money for the purchase of new lands to complete what is known as the Greater Campus, and the act included also an item authorizing the erection of Engineering Buildings in the sum of $250,000, upon the new Campus.

The Campus Act did not appropriate a given sum of money outright, but it authorized a tax levy to cover a period of four years beginning with the year 1907, and to secure $175,000 for each of these years. The first money available under this tax levy could not come into the State Treasury before 1908, and the aggregate sum, $700,000, was not due until 1911. The bill, however, provided that the Regents might borrow money in advance of the collection of the taxes, and issue certificates of indebtedness bearing interest. The act, however, failed to provide for the payment of interest from any other fund, and the interest on the certificates issued has been paid from the money available under this act.

After the passage of the Campus Act and by the terms of the Act, the College of Engineering was compelled to await the purchase of land before proceeding to erect its buildings. It is fortunate that the College did defer construction not only to such time as the new lands of the Greater Campus were purchased, but until an adequate project was formed. Viewing this matter from the present outlook the College and the University are to be congratulated that no hasty action was taken to get the buildings under way. It would have meant for the College a possibly poorer location, less space, architectural treatment not in harmony with the fine Gilbert plans, and it would have meant the expenditure of a portion of the money for equipment. It was much wiser to await the full

*Dean of the College of Engineering, University of Minnesota.

purchase of the lands appertaining to the Greater Campus, and the adequately developed scheme which embodies the possibility of a great Engineering School.

By the time tthe legislature of 1909 met the sum appropriated by the preceding legislature had been proved insufficient for the Greater Campus alone, and the legislature of 1909 provided for an additional sum of $350,000 to be raised in the tax levies of two more years. The final money to be collected under this act will not be in the State Treasury before 1913. The Regents, however, were authorized as before to raise money by issuing certificates of indebtedness.

When one is to build the first consideration is the lot, the land to be occupied. In the case of the new lands acquired for the Greater Campus the securing of all titles was not effected until a few months ago. The second thing, is to decide upon the nature of your buildings, and the style of architecture in which they are to be embodied. In the case of our new Engineering Buildings, as they form a part of a great constellation of buildings making up the University as a whole, it was desirable to complete a project for the entire Greater Campus and the buildings to be placed upon it according to a definite scheme with definite architectural relations. It is well known that the scheme which is being carried out at Minnesota is one of fine elaboration, ranking second to no Campus lay-out in the country, and is known as the Cass Gilbert Plan, —Cass Gilbert being one of the world's great architects, and incidentally the designer of the Capitol at Saint Paul. The Cass Gilbert plans with the various water colors illustrating them, and a plaster Paris cast of the Campus, were received last May.

Meanwhile it had been decided to build in the Engineering group a Main Building and an Experimental Building, and plans had matured to such an extent that the Architect was instructed to proceed with the working drawings. As the plans progressed it became evident that the money available, $250,000, was not enough to complete the buildings in their full proportions, much less to equip them as was desirable. It was decided, therefore, to use all the money available for the buildings themselves, to ask the legislature of this year for an additional $75,000 to complete the Main Building, and to ask also for another $75,000 for equipment. It is well known that the legislature with the wise foresight and business prudence characteristic of our law makers has appropriated the money for the completion of the building and has given us in addition the amount requested for the equipment,

less twenty per cent. We are hoping that before the legislature adjourns the remaining twenty percent may be given us.

The Engineering Group on the Greater Campus occupies a plot of ground about ten acres in extent, lying to the north of Washington Avenue, and reaching well towards the Northern Pacific Railway cut. It extends from Union Street on the east to the vicinity of State Street on the west. The group of buildings as projected comprises ten separate structures. (See Plate I).

It is hoped that ultimately the land available for the Engineering Group will be extended eastward to Harvard Street.

In selecting the buildings to be constructed, it seemed desirable to place the important Department of Experimental Engineering in a building where it would have ample opportunity to expand, and fully meet the requirements of the College and the profession. It was decided further that a Main Building, to contain the elements common to all Departments of the College was most desirable. It is hoped to secure two years from now an adequate appropriation for a New Electrical Building, and four years from now to have money available for a New Mechanical Building and Shops. When this shall have been accomplished the Engineering College will be compacted in a single business-like group of its own, instead of being scattered as at the present time.

The Main Building is the central building of the group shown on Plate I. The outside dimensions of the main body are roundly 231 by 65 feet. The wings will have dimensions of 40 by 80 feet each. The wings include well lighted basements and two stories; the main building has a basement, three stories, and a roof house, or texas.

The architectural style is shown in Plate 2. It will be seen to be of fine simplicity, noble and dignified. It is denominated by architects the Italian-Renaissance. The materials contemplated are gray stone for the base up to the level of the first story windows, the cornice above the first story windows, and for the cornice of the roof house; while the body of the building will be of Colonial brick. The stone and brick are to be similar, but not necessarily the same, to those used in the Elliott Memorial Hospital.

The construction throughout is to be fire proof, the floor systems being of reinforced concrete, using the Turner system, which imbeds in a rich concrete floor-slab long steel rods making a mesh of diagonal and transverse fibers much like a spider web. The main roof will be of reinforced concrete.

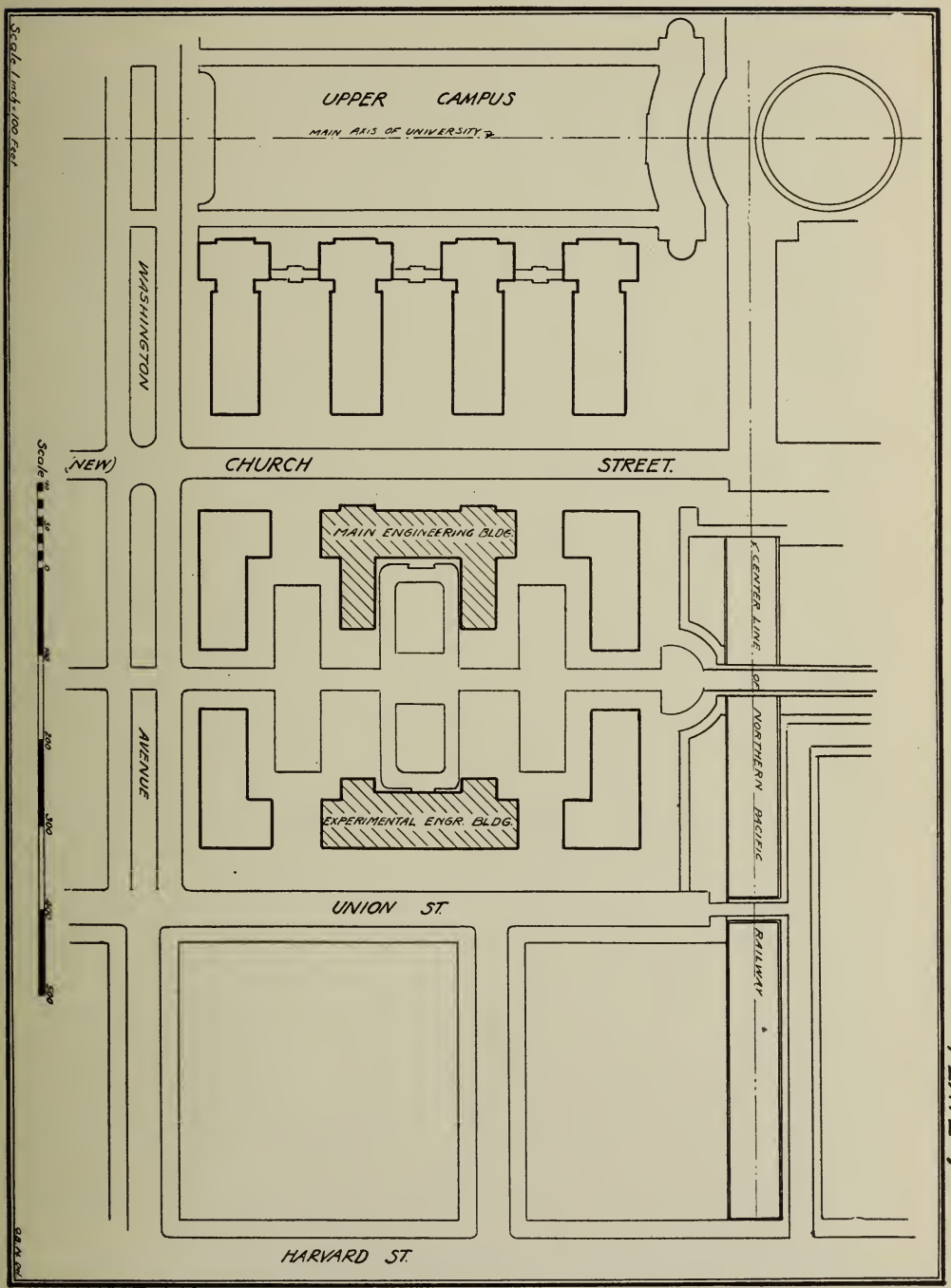
The roof of the upper house may be of concrete or of metal construction. This point is yet undecided.

In speaking of the basement thus far it has not been stated that below the basement floor is a space, perhaps six or seven feet high, known as the sub-basement. This space is unfinished but contains the many pipes, flues, and conduits that might otherwise disfigure and block the basement itself. The use of this sub-basement makes the basement a much more commodious, finished and pleasant place to work or play in.

The Building is to be modern in every respect in all matters of heating, lighting, ventilation and communication. The heating will come from the Central Heating system at the west end of the Campus by way of the tunnel now being driven under the Campus. The heating system is known as the Paul system and has a vacuum return. The direct radiation provided by low radiators under the windows in each room will be sufficient to heat the building even though the fans of the ventilating system are at a stand still. When the ventilating system is in operation warm air heated to perhaps seventy degrees will enter the room through openings close to the floor level and reinforce the heating power of the direct radiation.

The ventilating of a modern school building is of vital importance. It is a matter of daily observation that students working in ill-ventilated rooms lose the keen, fine mental grasp of wide awake men. The impure air exerts a drug effect and the men tend to become sleepy and listless. In the Engineering Building thirty cubic feet of fresh pure air a minute will be provided for each occupant of a recitation or lecture room. In drafting rooms and other rooms not densely occupied the air will be completely changed every ten minutes. It is hoped that the health and working capacity of the students will be better by reason of this sanitary provision for fresh air.

The ventilating plant itself is contained in a room whose floor is on the level of the sub-basement and extends up to the level of the first floor. In this room motor-driven Sirocco fans suck in the fresh outside air and force it into a plenum chamber. From this chamber it passes by many conduits to the various rooms of the building. The impure air is forced by the pressure of the pure incoming air through ventilators near the ceiling of the room out through the roof. Returning to the fan room in the sub-basement we find the air from the outside passed first through tempering coils of heating pipes. This takes the chill from the wintry air. The air then passes through a spray of water which gives it added


Scale 1 inch = 100 Feet
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MAIN AXIS OF UNIVERSITY
WASHINGTON
(NEW)
AVENUE
CHURCH
STREET.
MAIN ENGINEERING BLDG.
EXPERIMENTAL ENGR. BLDG.
UNION ST.
HARVARD ST.
CENTER LINE OF NORTHERN PACIFIC RAILWAY
Scale
0
100
200
300
400
500

PLATE-I

humidity and at the same time washes from it all dust particles. After passing through the spray the air enters the main heating coils, where it is brought up to a temperature of perhaps seventy degrees and is ready for use in the conduit system. It will be seen that the ventilating and heating systems are inter-connected.

In addition to the plenum or pressure system of ventilation, all toilet rooms are provided with suction or exhaust facilities to make the removal of impure air more complete.

The Building is to be provided with thermostatic control, that is with devices that turn on heat when the temperature of the room drops to a certain point, and turn it off again when it rises to the desired temperature.

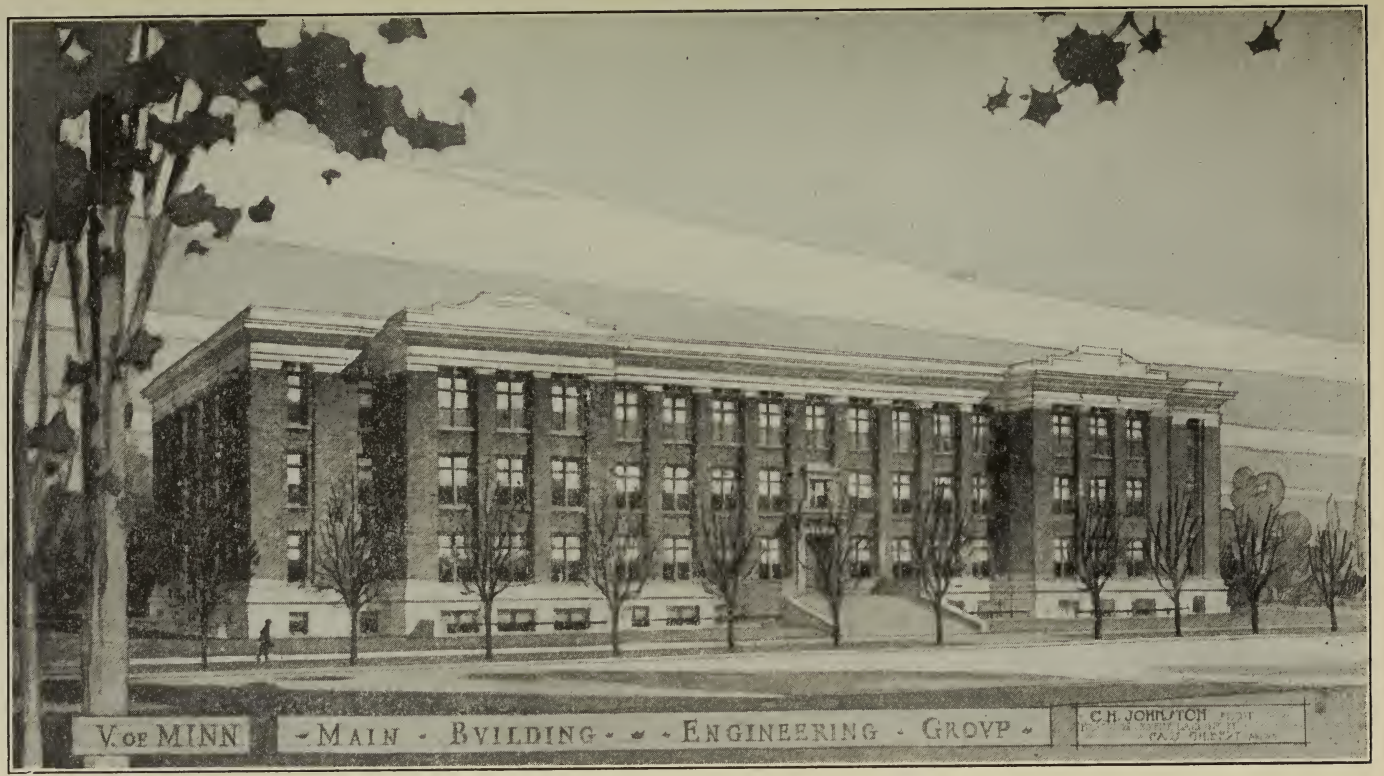
The Building is to be electrically lighted, and the lighting is to be such as to brilliantly illuminate the rooms. In this matter of lighting it will be assumed that the Universtiy will have the advantage of the new High Dam in the Mississippi River, and generate its own electric current by water power at such trivial cost, as will make economy in our lighting bills of little moment.

The Building is to be provided with conduits for intercommunicating telephone systems. It is also to be provided with the vacuum cleaning system. Of course plumbing and sanitary appliances of the most modern design are provided.

Before leaving this matter of the internal mechanical equipment of the Building it may be said that the many pipes, vents, cables, etc., which have been spoken of as traversing the sub-basement will rise vertically through ample spaces in the partitions separating the corridors from the front and back rooms. That is, the long partitions flanking the main corridors will be two feet thick, with internal spaces contained between the facing walls.

Before taking up the detailed lay-out of the several floors it will be well to note the general purpose of the Main Building. It is intended to house the administration of the College, including all things which are common to all departments and to all students. It will also provide for the uses of the graduates of the College, and for all Engineers of the Twin Cities, and of the State of Minnesota who may wish to avail themselves of our facilities to do better work, or to work with higher efficiency. It is hoped that the Engineering Group will form a focal point for the Engineers of Minnesota. It is believed that it will be the best thing for the students to come in contact with practical Engineers. It will be an excellent thing also for practicing Engineers to know the young men

Plate 2



who are working towards their degrees. In the end the College itself is a Public Service Corporation, and must do many things for the people of the State, and for the Government of the State, utilizing to the utmost its function as a Corps of Engineering Specialists.

It must be expected that the Main Building will be the heart of the College, and will appertain to no single Department. It is hoped that every Department in the College except the Experimental Department, will occupy offices in this Building, and, so far as may be to hold their recitations, their lectures, and have their drafting rooms here. The Mechanical and Electrical Departments for a few years will retain their laboratories and shops in the present old buildings, at least in part. The auditorium in which the College assemblies will probably be held is in the Main Building. The central library, which it is hoped will ultimately be one of the ranking Engineering Libraries of the country, will be contained in one of the wings of the Main Building. The rooms for the convenience and comfort of students, and their associations will be in the Main Building. Faculty rooms and committee rooms pertaining to the College as a whole will be in the Main Building, as will be the offices of the Dean of the College.

The basement floor level is about four feet below the ground surface outside the Building. Areas permit deep long windows for the basement giving it adequate light; the ventilation already referred to will insure sweet, pure air. For these reasons the basement is most servicable. It is to be utilized for research rooms, for instrument rooms for the Civil Department. for a laboratory devoted to instrumental calibration adjustment and practice. Three large rooms are provided for student purposes, one for the Engineers Society—a fine corner room—then a large room where the students may get together and have some social activity, and a third large room where students may eat their lunches if they so desire. In addition large locker rooms are provided, and adjoining these are fine toilet rooms with one room for shower baths. A student who has been exerting himself, as students frequently do when accomplishing a great deal of work, may wash away the perspiration in a refreshing shower bath.

It has not been considered desirable to have the full plans of the Buildings illustrated at this time. As the architect is still at work on the details of the wings of the Main Building, in some small matters the layout of the body of the Building may be modified. It will be desirable, however to get a fairly clear conception of the lay-out. The entrance to the Build-

ing, as shown in Plate II, is at the middle of the Building. On the opposite side is a smilar entrance. These two entrances come together on the main corridor which extends lengthwise of the Building and has a width of about twelve feet. In passing, it may be said that the floors of the corridor will be provided with some covering which will silence as far as possible all foot falls of hurrying students. These corridors are repeated in the basement, and in each floor except in the roof-house. From these corridors side halls lead to the wings, and at about one third of the length of the Building at each end are stairways ascending and descending. Towards the north end an elevator shaft is provided running from the basement to the roof house. The elevator will not be for other than exceptional use.

The first floor is to be devoted mainly to recitation, lecture and office rooms. It provides a Faculty room (where the Students Work Committee will hold receptions) and the Dean's offices. The north wing will contain the main floor of the general Engineering Library. It is expected that this will be a room about 37 by 70 feet, that the basement under it will be utilized for library purposes, that galleries on the level of the second floor will provide for great book storage capacity, and that the library will have overhead as well as side lighting.

In the south wing the first and second floors are devoted to drafting rooms.

The second floor is divided up with a view of making good recitation, lecture, drafting and office rooms. So far as may be, the Harvard unit is used in the dimensions of recitation rooms. This unit is a room 24 by 30 feet. Lecture rooms are considerably larger. Drafting rooms are placed so as to secure north light preferably and after that east light. The afternoon sun is not good for drafting work.

The third floor contains the auditorium, seating 400 persons. Its ceiling will have a height of perhaps 24 feet. The floor itself will be level with a view of making the room available for such student functions as are desirable. There seems to be no good reason why some of the social activities which the students so much enjoy should not be fully considered in the design of our Main or Home Building. The third floor contains drafting rooms, recitation and office rooms. As first blocked out it contains also studios for the Architectural Department. It is probable, however, that the Architects will prefer to occupy the uppermost rooms in the Building so that

they may have in addition to side lighting so much of over head lighting as may be desirable.

Of course certain rooms for blue printing, photography, storage, etc., are fully provided, including janitor's rooms, closets, toilet rooms, and so on.

It is aimed to make our Post-Senior year most attractive, and as near like the work of the practicing Engineer as may be. To attain this end student offices will be provided and assigned to post-senior students, either two or four in each office as our facilities may determine.

The finish of the Building throughout is simple but good and substantial. No money has been spent in elaboration but much for business facility and efficiency .

The Experimental Building, as shown in Plate 3, is a comparatively low building. It faces the wing side of the Main Buildings, is built of the same materials, and is substantially the same in the detail of construction. The Experimental Building is simpler in its architectural effect in the fact that it utilizes more brick and less stone.

On the Union Street facade the windows are big and the appearance of the Building is more that of a shop than of a College building.

The west approach leads to a vestibule and hall with offices on either side for the use of the members of the Department. The hall then leads directly into one room having inside dimensions of about 57 by 227 feet. This great room reaches up to the roof, and has in addition to the fine side lighting over-head lighting. It is to be traversed in its full length by a traveling crane of ten tons capacity. The floor of the main room is of heavy reinforced concrete slabs so that an ordinary engine or machine may be set at any point without fear of breaking through.

Along the east side of the room a gallery extends the full length of the Building, and this is enlarged into a series of computing and drafting bays at the center of the Building. Opening off from the balcony is a large computing and drafting room to supplement the open balcony space. Another big room is for use as a museum.

On the main floor in addition to the large room already described and the first room mentioned, is a lecture room, and a room for a machinist and an adjoining instrument room.

In the basement, rooms for cement and concrete testing and for experiments on road materials are provided. In addition space in this room will be partitioned off for rooms for special tests. The basement is fairly well lighted from side

Plate 3.

--V. OF MINN.-
--EXPERIMENTAL-BVILDING
ENGINEERING-GROVP.
C.H JOHNSTON
CA.U GILBERT

windows, and is also lighted through the main room by hatchways or openings along the axis of the building.

It is well understood that the Experimental Building will be utilized for all sorts of tests and experiments, from the testing of steam engines, gas engines, refrigerating and pumping machinery, and the breaking of columns and beams, to the twisting of rods, and the breaking of briquets, through the whole list of standard tests, including the calibration of weirs and the measurements of flow through orifices, short tubes, nozzles, meters, and so on.

It is intended that this Experimental Department will be developed in every direction desirable. It has been proposed to conduct high tension tests in electrical work here, but this has not been fully decided up on. The great amount of detail in the Experimental Building makes it undesirable to more than touch on the general outline in this article. It may be said of both Buildings that more detailed dexcriptions may be desirable later on, and that these may be illustrated by some of the photographs taken during the progress of the construction.

It is well known that the two Engineering Buildings described are under construction, and that the Experimental Building will be ready for use in September of this year. The Main Building on the other hand will not be ready for occupancy before April of 1912.

SOME STANDARD PRESERVATIVE TREATMENTS FOR RAILWAY TIES WITH RESULTS

Day Okes. C. E. '08*

It will be attempted to show in this paper the investment which is justified for the preservative treatment of ties based on the present costs and the results obtainable.

The preservation of ties is, broadly speaking, a question of economy involving the conservation of timber and the assurance of a reduction in the annual charge per mile of road for ties.

The question of conservation of timber has been thoroughly discussed and it is evident that if timber thru treatment is given a longer life, the annual consumption for a required purpose would be less. The Railway Manager is interested primarily in the reduction of the annular charge per mile of track for ties. He is confronted with the problem of choosing the treatment which, under the local conditions to which his ties are subjected, will make the preserved and the mechanical life of the tie practically equal. The treatments which are in general use, and considered standard under certain conditions, are as follows:—

Burnettizing, requiring ¼ to ¾ pounds of zinc chloride per cubic foot of timber.

Creosoting—Full cell and empty cell treatments, requiring from 4 to 10 pounds of creosote oil per cubic foot.

Zinc—Creosoting, in which an emulsion is made of zinc chloride and creosote requiring ½ pound of zinc and 2 to 3 pounds of creosote per cubic foot.

Empty cell treatments have been in use since 1904 in this country and the methods adopted are patented and as follows:

Reuping—originally a German patent, under which air is first injected into the timber followed by the injection of creosote oil at a higher pressure. This compresses the air in the wood cells and when the pressure is released, a portion of the oil is rejected from the wood cells, due to the internal pressure. This allows the painting of the inside of the wood cells without the high cost of leaving a large amount of oil in the timber.

Lowry—The claim made for this process is also a minimum amount of oil left in the wood. Pressure is first applied, and

*Chief Engineer, The Kettle River Company, Minneapolis, Minn.

Acknowledgements are due to Walter Buehler, M. Am. Soc. C. E., and F. J. Angier, Timber Treating Engineers, for many helpful suggestions.

after releasing and the oil taken from cylinder, a quick vacuum is applied and more or less of the oil first injected withdrawn.

Buehler—This process can be used either for a full or empty cell treatment. Under this system first is injected the amount of oil which is called for under the specifications and then by a subsequent high air pressure this amount of oil is forced into the timber. When the air pressure is taken off there is a consequent slight kick back and rejection of oil but to surface of tie only, inasmuch as the internal air pressure adjusts itself to the external air pressure.

The Zinc-Creosote treatment, which is a combination treatment in which the creosote oil and zinc are mixed by a centrifugal pump and then injected into the timber, using ½ pound of zinc per cubic foot and from 2 to 3 pounds of creosote oil per cubic foot, aims to get a heart penetration with the creosote. It is claimed for this process that the leaching of the zinc is eliminated by the outer coating of creosote treatment.

Of the foregoing named treatments, The Great Northern Ry. used ¾ pounds Zinc per cu. ft; The Chicago-Great Western Railway uses ½ pound of zinc per cubic foot in their ties; the Union Pacific uses ¼ pound of zinc per cubic foot, the C. M. & St. P. uses ½ pound of zinc per cubic foot. The Pennsylvania Railway uses 8 pounds creosote oil per cubic foot full cell treatment. The Lowry Process, with injection of 6 lb. of oil per cubic foot is used by the Northern Pacific Railway and the C. R. I. & P. Railway. The Buehler Process, with injection of 6 pounds of oil per cubic foot is used by the C. P. & St. L. Railway, the McKinley Traction System and Chicago & Alton Railway. The Tri City Railway Company uses 5 pounds of creosote oil per cubic foot, under the Buehler Process for ties laid in concrete. The zinc-creosote or Card Process, using ½ pound of zinc and 3 pounds of creosote oil per cubic foot is the standard treatment of the C. B. & Q. Railway; using ½ pound of zinc and 2 pounds of creosote oil per cubic foot of the Baltimore & Ohio Railway and Chicago & Northwestern Railway.

In discussing the life resulting from treatment, many individual examples could be selected showing that treatment produced a life for ties of from 15 to 25 years. However, under general conditions and practice in railroad construction, the mechanical life of the tie does not exceed a maximum of 20 years and it is the conditions under which ties are to be laid which govern the treatment to be chosen for the timber, for it is possible under the various treatments to obtain a

preserved life that is much greater than the mechanical life of the tie.

The general average of the life of white oak ties (not treated) reported by twenty-two- well-known railroads of the Northern States, located both east and west of the Allegheny mountains, is eight and one-fourth years, according to a report made by the American Railway Engineering & Maintenance of Way Association. The figures taken into account in this average were supposed to represent the life of ties which had failed by natural decay and not by rail cutting. In the Southern States the life of white oak ties is said to average five or six years.

A committee that investigated the treated ties on the Illinois Central Railroad, reported that red oak, gum and beech treated with zinc chloride will last at least double that of white oak ties in the South and equally as long as white oak in the North; and that the percentage of failures so far found is less than white oak in all localities.

This report says,—

"The best idea of the performance of red oak sinc treated ties, is to compare them with the white oak in the same territory, as noted below:

LOCATION	SERVICE	PER CENT OF FAILURES	
			Treated
		White Oak	Red Oak
Tennessee Division	6 years	30%	1.5%
Tennesesse Division, Cairo to Paducah	6 years	10%	1.5%
Silver Creek District	3 years	40%	0.0%
Omaha Division	6 years	9%	0.0%

The following is taken from a paper written by C. T. Barnum, appearing in the Journal of the Western Society of Engineers for June, 1910:

"Properly creosoted ties can be made to last until destroyed by mechanical wear, and if protected against this wear can be made to give twenty to thirty years' service. With the proper kind of treatment, a pile can be made to last from twenty- to twenty-five years. The L. & N. R. R. Co. in 1882 used larger quantities of creosoted piles, stringers and caps, in the construction of trestles and docks, in the vicinity of Pensacola, Fla. All of this material gave a service of over twenty-five years.

"The Forest Service has estimated that proper preservative treatment will increase the life of ties over 200 per cent, poles 100%, posts 300%. piles 700%, mine props 400%, and lumber 300%. These figures are made up of the average estimates of treated and untreated life for the various forms all thru the

country, and under all conditions, so they naturally give merely an indication of the results of treatment which, in specific instances, may be much more or less than the general average."

Mr. Octave Chanute said that when he began work in timber preservation, about 24 years ago, they followed the German practice of injecting about ⅓ pound of zinc chloride in a cubic foot of timber, and obtained an average life of 11½ years with hemlock and tamarack ties. Since then we have ascertained that the Germans, in their extended experience, have increased the dose to ½ pound per cubic foot, and with that they are now obtaining results (now 10 years old) which promises a life of 14 to 17 years in the track.

He further stated that if creosote be thoroughly injected into wood with the full cell process, the results which have been obtained in Europe show that a life of 20 to 27 years can be obtained. But there is one element there which does not obtain in this country. The rolling stock on the European railroad is light; the weight per wheel is limited to about 10,000 pounds, while the weight of our modern freight cars is much greater. For instance, a car weighing 49,000 pounds and carring 100,000 pounds will give wheel pressures of about 18,000 pounds per wheel. Those weights are all producing mechanical wear, so that the ties, whether treated with zinc chloride or creosote, are going to be destroyed by mechanical wear sooner than by decay. In this country ties used on Electric Railways due to lighter rolling stock generally are not subject to as great mechanical strains as those on steam roads.

The Committee on Wood Preservation of the American Railway Engineering & Maintenance of Way Association, in their 1909 report, gave some preliminary deductions based on statements received from 36 to 39 members of the Association who were selected as likely to possess information relative to the life of treated timber:

(1) "Creosoting may be relied upon to preserve piles from 20 to 25 or more years, if they are injected with 16 to 24 pounds per cubic foot.

(2) "Creosoting at present cannot be relied upon to preserve ties more than 15½ to 19 years, an absolute maximum, unless the ties are protected against mechanical destruction. If badly injected, they perish from decay in 5 to 12 years.

(3) "Burnettizing, when well done, can be relied upon to preserve ties from 10 to 14 years. The amount of injection varies with the proposed subsequent exposure. In arid climates ¼ pound of dry zinc chloride per cubic foot may give

good results. In moist and warm climates not less than ½ pound per cubic foot should be injected. There are great differences in the thoroughness with which the work can be done.

(4) "The zinc creosote process has been too recently introduced (1904) in this country to give definite conclusions; it has given ties a life of 12 to 18 years in the track in Germany."

In another report by this same Committee they say that untreated white oak ties last 7 to 12 years, pine 5 to 8 years, chestnut 8½ years, cedar 15 years, tamarack 5 to 6 years, hemlock 5 years, cypress 7 to 9 years. Seventy-five to 98% of white oak ties fail from decay, and 2 to 25% from rail and spike cutting; 75 to 90% of other ties fail from decay, and 10 to 25% from rail and spike cutting.

The cost of the plant of the various treatments figured on the basis of the use of a standard 6x8-8 cross tie would be for ½ pound of zinc per cubic foot, Sixteen Cents (16¢) per tie; for full cell creosote treatment, using 6⅔ pounds of oil per cubic foot, Twenty-eight and One-half Cents (28½¢) per tie; and with 8⅓ pounds of oil, Thirty-one Cents (31¢). For the empty cell treatments, using 4 to 6 pounds of oil per tie, the cost would be approximately Thirty-one Cents (31¢). For the zinc creosote or Card Process, the cost would be about Twenty-four Cents (24¢) per tie.

The economy of the use of the various treatments is shown in tables attached, based on the cost of untreated white oak ties at Sixty-five Cents (65¢), and untreated inferior timber ties, such as red oak, gum, etc., at Forty-five Cents (45¢). These figures naturally vary with the timber and treatment market but the relation of their cost remains practically fixed and so the comparative results shown in the table would generally prevail. The life assumed for the untreated white oak tie is the average shown by extended experience by railways as stated in the report of the Railway Maintenance of Way Association.

From the assumption as to the cost and life of untreated white oak ties and the various standard treated ties the following tables are worked out.

Table I. Shows how long ties of different materials and treatment must last in order to be as economical as white oak costing 65¢ and lasting 8 years. The resultant necessary life of treated ties for economical use as worked out here are below

the minimum shown by experience.

In Table II, on the basis of an assumed life for the various treated ties indicated by the experiences outlined above in this paper, are figured the first cost which can be paid for different kinds of ties in order to be as economical as white oak costing 65¢ and lasting 8 years.

Table III is a readjustment of the table II, showing the cost which a white oak tie must reach before it will be economical to use the various treated ties at their assumed life and cost . Line 16 of table III indicates the great economy resulting from the use of treated ties.

TABLE I.

How long ties of different materials must last in order to be as economical as White Oak costing 65 cents and lasting 8 years

Line	Letter of Formula	Description	White Oak Un-treated	Inferior Woods No Tie Plate					Inferior Woods With Tie Plate		
				Zinc Chloride	Card. Process	1½ gal Creosote	2 gal Creosote	2½ gal Creosote	Zinc Chloride	Card. Process	2½ gal. Creosote
1		Life which tie must have in years	8	7.61	8.4	8.8	8.8	9.27	13.98	15.1	16.3
2	i	Assumed rate of interest	4	4	4	4	4	4	4	4	4
3	s	Annuity to redeem $1.00 during life of tie	.1085	.1155	.1018	.1001	.0965	.0914	.0548	.0495	.0454
4		Spacing of ties c. to c. in feet	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833
5		Assumed cost, tie delivered	.65	.45	.45	.45	.45	.45	.45	.45	.45
6		Cost of treating tie		.16	.24	.25	.285	.31	.16	.24	.31
7		" " putting in tie	.12	.12	.12	.12	.12	.12	.12	.12	.12
8		" " 4 track spikes	.064	.064	.064	.064	.064	.064			
9		" " 4 Wood screws							.15	.15	.15
10		" " 4 helical linings							.03	.03	.03
11		" " 2 tie plates							.32	.32	.32
12		" " application of fastening	.03	.03	.03	.03	.03	.03	.12	.12	.12
13		Total cost of tie in track	.864	.824	.904	.914	.949	.974	1.35	1.43	1.50
14	c	Cost of tie per lin. foot of track	.471	.449	.493	.498	.517	.531	.736	.780	.818
15	x	Annual cost of ties per lin. foot of track	.0698	.0698	.0698	.0698	.0698	.0698	.0698	.0698	.0698
16		" " " " mile " "	368								

FORMULA $s = \frac{x - ci}{c}$

TABLE 2.

First cost which can be paid for different kinds of ties in order to be as economical as White Oak costing 65 cents and lasting 8 years.

Line	Letter of Formula	Description.	White Oak Un-treated	Interior Woods No Tie Plate					Interior Woods With Tie Plate		
				Zinc Chloride	Card. Process	1½ gal Creosote	2 gal Creosote	2½ gal. Creosote	Zinc Chloride	Card. Process	2½ gal Creosote
1		Assumed life of tie	8	12	14	14	18	20	18	24	30
2	i	" rate of interest	4	4	4	4	4	4	4	4	4
3	s	Annuity to redeem $1 oo during life of tie	.1085	.0665	.0547	.0547	.0390	.0336	.0390	.0259	.0178
4		Spacing of ties c. to c. in feet	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833
5	D	Maximum cost delivered which tie can have	.65	.83	.90	.89	1.12	1.215	.72	.965	1.165
6		Cost of treating tie		.16	.24	.25	.285	.31	.16	.24	.31
7		" " putting in tie	.12	.12	.12	.12	.12	.12	.12	.12	.12
8		" " 4 track spikes	.064	.064	.064	.064	.064	.064			
9		" " 4 wood screws							.15	.15	.15
10		" " 4 helical linings							.03	.03	.03
11		" " 2 tie plates							.32	.32	.32
12		" " application of fastening	.03	.03	.03	.03	.03	.03	.12	.12	.12
13	E	Total cost of tie in track	.864								
14	c	cost of tie per linear foot of track	.471								
15	x	Annual cost of ties per lin. foot of track	.0698	.0698	.0698	.0698	.0698	.0698	.0698	.0698	.0698
		" " " " " mile " "	369								

FORMULA $c = \frac{x}{[i + s]}$ $D = c \times 1.833 - [E - 45]$ [tie.

NOTE — The sum of costs in lines 5 and 6 for any treatment is the economical maximum delivered cost of treated

TABLE 3.

Cost delivered which a White Oak tie, lasting 8 years, must reach before it will be economical to use the treated tie heading the respective column of the table.

Line	Letter of Formula	Description.	White Oak Un-treated	Inferior Woods No Tie Plates					Interior Woods With Tie Plate		
				Zinc Chloride	Card Process	1½ gal. Creosote	2 gal. Creosote	2½ gal. Creosote	Zinc Chloride	Card. Process	2½ gal. Creosote
1		Assumed life of tie in years	8	12	14	14	18	20	18	24	30
2	i	" rate of interest	4	4	4	4	4	4	4	4	4
3	S	Annuity to redeem $1.00 during life of tie	.1085	.0665	.0547	.0547	.0390	.0336	.0390	.0259	.0178
4		Spacing of ties c. to c. in feet.	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833	1.833
5		Assumed Cost of tie delivered	.65	.45	.45	.45	.45	.45	.45	.45	.45
6		Cost of treating tie		.16	.24	.25	.285	.31	.16	.24	.31
7		" " putting in tie	.12	.12	.12	.12	.12	.12	.12	.12	.12
8		" " 4 track spikes	.064	.064	.064	.064	.064	.064			
9		" " 4 wood screws							.15	.15	.15
10		" " 4 helical linings							.03	.03	.03
11		" " 2 tie plates							.32	.32	.32
12		" " application of fastenings	.03	.03	.03	.03	.03	.03	.12	.12	.12
13		Total cost of tie in track	.864	.824	.904	.914	.948	.974	1.35	1.43	1.50
14	c	Cost of tie per lin. foot of track	.471	.449	.493	.498	.517	.531	.736	.780	.818
15	x	Annual cost of tie per lin. foot of track	.0698	.0478	.0466	.0471	.0408	.0391	.0581	.0514	.0472
16		" " " " " mile " "	369	252	246	249	216	206	306	271	249
17	c_1	Cost delivered which a white oak									
		must reach before it will be		.381	.360	.368	.290	.269	.505	.420	.369
		economical to use tie at head of column									

FORMULA $c = \frac{x}{i+S}$ $c_1 = c \times 1.833 - 21.4$

ELEMENTARY THEORY OF THE ALTERNATING CURRENT MOTOR

Geo. D. Shepardson, Professor of Electrical Engineering

A paper read before the Minnesota Electrical Association, March 1911, and revised for the Minnesota Engineer.

Alternating current motors are often looked upon as being shrouded in mystery into whose depths none may enter without first having been initiated into abstruse scientific realms and having passed the third degree in mathematics and several higher degrees in its applications.

It is unquestionably true that the principal steps in the development of the motor have been made by men of scientific training. It is also true that mathematics have played very important parts in predicting and in explaining many of the actions of the motor. Mathematical analysis has frequently indicated the way for improvements and for radical changes in design. Mathematical analysis has pointed out sources of danger and has explained otherwise inexplicable phenomena. Nevertheless, the performance of the ordinary motor may be explained at least in a general way, by the simple application of elementary principles which do not necessarily involve any great amount of mathematics.

This paper is an attempt to explain the performance of the most common types of alternating current motor, as modified direct current motors.

The operation of an electric motor, whether direct or alternating current, may be explained by a few comparatively simple and well-known laws.

The FIRST LAW is that of the MAGNETIC FIELD. Every current is surrounded by a magnetic field. If the wire is wound into a coil, the magnetic effect is more concentrated. The amount of magnetism, or the number of magnetic lines of force, caused by the current is directly proportional to the number of amperes and to the number of turns or convolutions in the coil. The amount of magnetism is also proportional to the excellence of the magnetic circuit, which should be as short as practicable and through soft iron for as much of the path as is practicable.

The SECOND LAW is that of INDUCTION. Whenever a conductor moves in a magnetic field, or whenever a magnetic field moves past a conductor, or whenever there is any change in the amount of magnetism enclosed by the circuit, an electromotive force is induced in the conductor proportional to

the rate at which the magnetic lines pass it; this equals the product of the intensity of the magnetic field, times the length of the wire in the field, times the relative velocity between wire and field. In the transformer the copper wires and the iron core both remain stationary, but the magnetic field changes its strength and reverses its direction with every alternation of the primary current; in the direct current dynamo and motor the magnetism remains constant in strength and position, but the wires of the armature move in the field; in the synchronous alternating current motor the magnetism remains of constant strength except as effected somewhat by the alternating current in the armature, its position in space being constant with revolving armature machines, or rotating in space in revolving field machines.

The THIRD LAW is that of MAGNETIC PULL or TORQUE. A current in a magnetic field tends to move across the magnetic field with a force proportional to the strength of the current, to the strength of the magnetic field and to the length of the conductor in the magnetic field. In the actual motor, the total pull on the armature is the net sum of the pulls on the individual wires in various parts of the magnetic field, some of which may be in the wrong direction. The equivalent pull at unit distance from the center of the shaft is often called the TORQUE of the motor; this is measured in terms of inch-pounds or gram-centimeters. The direction of the pull or torque in any wire depends on the direction of the current and that of the magnetic field; if either is reversed, the direction of the pull is reversed; but if both are reversed, the torque is in the same direction as before. Thus some motors work about equally well on direct or on alternating current circuits.

The FOURTH LAW is a modified form of OHM'S LAW. In any electric circuit at any instant the current is inversely proportional to the resistance and is directly proportional to the difference between the impressed electromotive force and any opposing or counter electromotive force existing in the circuit at that instant. When the counter electromotive force is due to induction from an alternating current, it is usually more convenient to use another form of Ohm's law, namely that the current is directly proportional to the applied electromotive force and is inversely proportional to the impedance. The rigid derivation of this form of Ohm's law usually involves a long mathematical process, but it may be shown reasonable by simple considerations. The total applied electromotive force is used up partly by overcoming the ohmic resistance, that is, by the "IR drop" and partly by overcom-

ing the electromotive force of self induction; as indicated by the second law mentioned, the electromotive force due to magnetic induction is proportional to the rate of change of the magnetic field; experimental study shows that the magnetism due to alternating current changes most rapidly when it is changing its direction and is passing through zero value, and that it changes slowly when its actual value is the greatest; thus the counter electromotive force, which is proportional to the rate of change of magnetism, is greatest when the magnetism and the current causing it are least; on the other hand, the ohmic drop is directly proportional to the current at each instant, being greatest when the current is greatest, and zero when the current is zero. If the time of a complete cycle of current and magnetism be considered as represented by 360 time degrees, then the epoch between the time of zero current or zero magnetism and of maximum current or magnetism would be represented by 90 degrees of time; then the greatest value of the IR drop is 90 degrees from the greatest value of counter electro-motive force; this is often expressed by saying that the ohmic drop is at right angles to the reactive drop. The total drop, which equals the applied electromotive force, is then obtained by taking the resultant of the two components at right angles; this, as is familiar to most mechanics, equals the square root of the sum of the squares of the two components. The reactive drop, by analogy with the ohmic drop, may be considered as the product of current by some factor, which for convenience may be called the reactance of the circuit; continuing the analogy, the total applied electromotive force may be considered as being or equalling the product of the current by some factor, which for convenience may be called the impedance of the circuit. The impedance then equals the square root of the sum of the squares of the resistance and of the reactance. Ohm's law then takes the form: the current equals the applied electromotive force divided by the impedance.

The FIFTH LAW is that of the COMBINATION AND RESOLUTION OF FORCES. Any number of forces may be combined to form a resultant whose direction and amount depends upon the directions and amounts of the components. The simplest case is that of two forces at right angles to each other, their resultant being equal to the square root of the sum of the squares; thus if a pull of 6 pounds in one direction be combined with a force of 8 pounds in a direction at right angles to the first, their resultant is a force equal to the square root of the sum of 36 and 64, which equals 10 pounds. The

resultant force makes an angle with the 6-pound force, the tangent of which is 8/6, that is 53 degrees. By the reverse process, any force may be considered as being the resultant of two component forces at right angles to each other, or in fact at any desired angle.

Thus suppose two magnetizing coils, A and B, placed 90 degrees apart in space, are arranged so as to magnetize the same central iron core or disc, somewhat as in Figure I. Suppose also that the two coils or sets of coils carry alternating currents which are 90 time-degrees apart, so that the current in A is at its greatest value when the current in B is zero, and vice versa. Then their resultant will continually change its direction as indicated in Figure II. When the current in coil A is at its maximum value and current in B is zero, the resultant magnetism is in the direction of the axis of coil A. resultant pull of 10 pounds is in a direction somewhere between the two components; to be exact, the direction of the

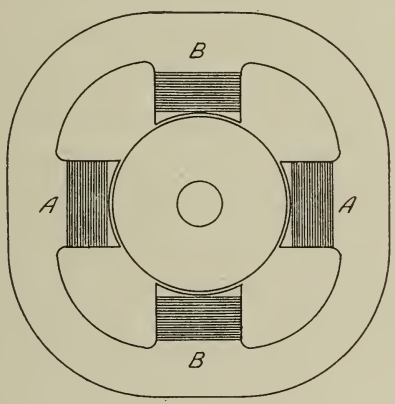


Figure I

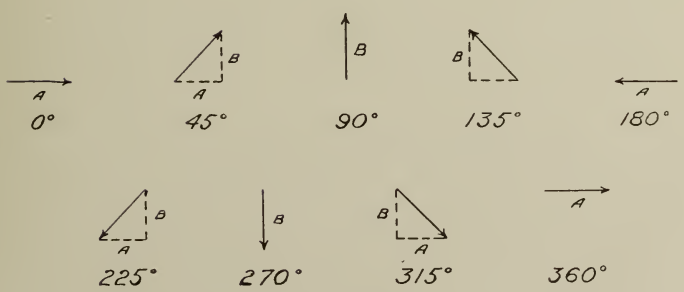


Figure 2.

When A becomes zero and B a maximum, the resultant is in the direction of the axis of coil B; for intermediate values the resultant is in intermediate directions. Thus when current in A has changed from a maximum value in one direction to a maximum value in the reverse direction, the resultant has also reversed its position. So the direction of the resultant makes a half revolution in space while the current passes through a half cycle in time. In other words, the magnetic field revolves synchronously that is, in the same time with the currents. If the two currents vary sinusoidally, and if the magnetic path is equally good in every direction, then the resulting magnetic field is of constant strength. In a similar way, three sets of coils equally spaced and carrying currents 120 time-degrees apart will give a revolving magnetic field which will be of constant strength if the three-phase currents are sinusoidal. A field revolving in synchronism is also produced when the currents in the two or three coils are not separated by exactly 90 or 120 degrees. Thus revolving field motors may be operated from single phase lines by arranging two electric circuits which have different relations between resistance and reactance, so that the two currents are unequally displaced or de-phased from the line electromotive force. This is the basic principle of single-phase induction meters and of many power motors.

It is desirable to note that there are several varieties of alternating current motor. They may be classified according to whether their speed is constant or variable; according to whether they are used on single-phase or on polyphase circuits; according to whether they have commutators or not; according to whether action depends entirely on currents supplied from outside sources or whether they depend partly upon currents induced within the motor.

Every alternating current motor has something corresponding closely with the field magnet of a direct current motor, and it has what corresponds more or less closely with the armature of such a motor. In direct current motors the field magnet is the stationary part and the armature is the moving part, this arrangement being caused by the necessity for a commutator and brushes and the greater mechanical convenience of having the commutator revolve rather than the brushes. Alternating current motors having commutators are governed by the same consideration and therefore have moving armatures and commutators with stationary brushes; but those not having commutators may have either the field or

the armature constitute the moving part. Since either field or armature may revolve, it is convenient to use special terms to designate them; thus the stationary part is called the STATOR, and the revolving part is called the ROTOR, but either rotor or stator may be the field.

If the field magnet has definite poles, one part being always a north pole and another part being always a south pole, and if the armature wires carry alternating current, then when the motor is standing still the pull will be first in one direction and then in the other, and the rotor will not revolve but will only tremble. But if the rotor is moving so fast that a given wire is in front of a north pole when its current is in one direction and it has moved to a south pole by the time its current reverses, then the pulls will be in the same direction. Thus the motor must in synchronism, so that the direction of the current in a given wire changes as fast as does the magnetic field; or else the pulls will be first in one direction and then the other, and the motor stops. If the motor runs at all, it must run at a constant speed which equals the frequency of the alternating current divided by the number of pairs of magnetic poles. Such a motor is known as a SYNCHRONOUS MOTOR because it makes a revolution in the same time with the generator (or some definite relation to it if the generator and motor do not have the same number of poles), the number of pairs of poles in the motor multiplied by the number of revolutions per second equalling the number of pairs of poles in the generator multiplied by the number of its revolutions per second, that is, equalling the frequency or the number of cycles per second in the current supplied to the circuit.

When the armature winding is suitably arranged and is connected at regular intervals with a commutator, the machine becomes what is known as a ROTARY CONVERTER for changing the power of alternating current into direct or vice versa; such a machine may be driven from either end, working as a combination of a synchronous current motor and a direct current generator, or as a direct current motor and an alternating current generator.

Synchronous motors have the disadvantage that they are not self-starting on singlephase circuits, but must be brought up to speed by some outside power before they may be safely connected with the alternating current circuit. On polyphase circuits they will induce their own magnetic field if the regular direct current field exciting current is cut off, and will thus come up to speed as induction motors; this is a common method of starting polyphase rotaries, the voltage of the sup-

ply circuit being temporarily reduced by auto-transformers in order to avoid excessive starting current, and the direct current field circuit being divided into a number of sections in order to divide the electromotive forces due to transformer action while the rotary is starting.

In addition to the advantage of running at constant speed regardless of changes in the load or in the line voltage, synchronous motors enable the operator to adjust the power factor so that the current taken by the synchronous motor either lags behind the line voltage or leads by any desired amount within certain limits. By giving the synchronous motor a strong magnetic field, it takes leading current and acts much like a condenser, supplying wattless component of the lagging current taken by induction motors. Synchronous motors are sometimes connected across the line for the sole purpose of taking in leading current, which is equivalent to giving out lagging current, and are then known as ROTARY CONDENSERS. By supplying the lagging components of the current near the load, the powerhouse and the line are relieved from carrying this current, and the regulation becomes much better.

Motors which do not run at synchronous speed, are called A-SYNCHRONOUS or NON-SYNCHRONOUS MOTORS. These include the induction motors and the commutator motors (not including the rotary converter, since its commutator is on the direct current side).

COMMUTATOR MOTORS are coming into extensive use, principally on single-phase circuits. Commutator motors for polyphase circuits have been proposed by several European engineers, but they seem not to have come into any use in America. The commutator motor having the field and armature circuits connected in series is equally suited for direct or for alternating current circuits (if properly designed), and finds a field where large starting power is required but where the speed may be controlled by hand such as for hoisting purposes and for operating railway cars or locomotives. Its most extensive use at present seems to be on the New York, New Haven and Hartford Railroad. The same laws which govern the direct current series motor also govern the design and operation of the alternating current series motor, except that greater care must be taken to laminate the fields to reduce eddy currents to a minimum, and more care must be taken to reduce the currents in the armature coils whose commutator bars are passing under the brushes.

In the series motor, whether for direct or alternating cur-

rent, the same current passes through the field coils and also through the armature; thus the torque increases much faster than the current. For example, if the current at one time is twice as strong as at another, the magnetic field is almost twice as strong; since both the magnetic field and the armature current are double, it follows that their product is four times as great. The series motor is thus well adapted for work requiring great starting torque. When the motor is standing still, the current is governed by the resistance (or by the impedance, if the current is alternating), and will be very large unless controlled by external resistance or by reducing the voltage. When several motors are on the same load, as in the case of an electric car, the voltage per motor may be reduced by connecting two or more motors in series at the start. As the motor comes up to speed, the motion of the armature wires in the magnetic field induces a counter electromotive force which opposes the line electromotive force and so reduces the current. Thus direct current motors on cars are generally coupled in series for slow speed and are then changed over to multiple so that for high speed each motor is coupled directly across the line and has full voltage applied.

In the case of series motors on alternating current circuits it is easier and more efficient to adjust the voltage applied to the motors by means of a transformer which has a number of coils or steps. In the series motor on alternating current circuits both the current in the armature and the magnetic field increase and decrease with each alternation of the current; consequently the torque is not steady, but it pulsates from zero to a large value once for each alternation, or twice for each complete cycle of current. The pulsations of torque, however, are in the same direction, since both field and armature current reverse simultaneously. Since the magnetic field through the field coils continually varies in strength and direction, there is induced in them a counter electromotive force according to the second law mentioned. This counter electromotive force is proportional to the rate of change of current and magnetic field and so is at right angles to or 90 time-degrees from the ohmic drop and from the counter electromotive force caused by the rotation of the armature. In order to reduce the effect of this reactive or wattless counter electromotive force, it is customary to design series motors with fewer turns in the field coils when intended for alternating current service. It is also necessary to build up the field magnet of sheet steel rather than of solid metal, in order to reduce

the production of useless and wasteful currents induced in the iron. A further peculiarity of the series motor on alternating current circuits is that electromotive forces are induced in the armature windings by transformer action as the magnetic field increases and decreases with each alternation of the current. Fortunately, the electromotive forces induced in this way in the various coils of the armature are in such directions that they balance and neutralize one another except in the coils connected with the commutator loss which happens to be under the brushes. The current in the coils thus short-circuited is reduced to harmless amount by inserting a small resistance in each lead to the commutator; the electromotive force causing such current is reduced by dividing the armature into many coils of few turns each, so that only a few turns are short-circuited.

REPULSION MOTORS are of two general classes: in one, such as the General Electric single-phase railway motor and the Kimble variable-speed motor, the brushes are always in contact with the cummutator; the other class includes such motors as the Wagner and the Century, in which the brushes are in contact with the commutator only during the period of starting. The armature of a repulsion motor of either type is usually wound practically the same as that of an ordinary direct-current motor, the various coils being connected in series so as to form one continous circuit, and being connected with the bars of a commutator against which two or more brushes make contact. The field winding is connected with the single-phase outside or supply circuit. As alternating current passes through the field coils, the magnetic flux through the field and armature cores rises and falls and reverses with each alternation of the current; this changing flux induces electromotive forces in the various coils of the armature and, if suitable paths are provided, these electromotive forces will cause currents to flow, and these in turn react upon the magnetic field and cause the armature to rotate.

Repulsion motors may be divided into two classes again, according to the width and connection of the brushes; one has wide brushes, each of which spans several commutator segments and thus short-circuits the armature windings between them, each brush being otherwise isolated and not connected with any other circuit; the other and more common class has brushes which are so narrow as not appreciable to short-circuit more than one individual coil, but which are connected together so as to short-circuit the entire armature through a single external path. In the motor with wide isolat-

ed brushes current passes through only those individual coils whose commutator bars are passing under a brush; in the motor with connected narrow brushes, induced current passes through the entire armature winding. If the brushes are properly placed, the induced currents cooperate and pull against the magnetic field so as to make the armature rotate and come up to speed. Shifting the brushes beyond a certain angle causes the currents in some coils to pull in the opposite direction and so to lessen the torque; this provides a means of obtaining a variable torque and consequently a variable speed, as has been developed in the Kimble variable speed single-phase motor. In other repulsion motors, such as the Wagner or the Century, after the armature comes up to speed, a centrifugal device lifts the brushes from the commutator and at the same time moves over the commutator a ring which short-circuits each individual coil and practically transforms the motor into an induction motor of the ordinary type, which will operate on single-phase current after being started, as will be explained later.

Alternating current motors, whether synchronous or non-synchronous, whether single-phase, two-phase or three-phase, whether commutating or not, may be divided broadly into two general classes: those in which the useful currents are wholly supplied from external circuits, and which for want of a recognized name may be called PRIMAL MOTORS; and those in which the essential currents are derived partly from external circuits and partly by induction within the motor, such being generally known as INDUCTION MOTORS.

The INDUCTION MOTOR is generally treated as a variety of transformer. Alternating current from the supply lines sends through the laminated iron circuit a magnetic flux which changes strength and direction with each alternation of the primary current; this alternating magnetic flux induces electromotive forces in the secondary circuits; the secondary currents, in proper time and space relations with the magnetic flux from the primary current, exert a pull in the magnetic field. The quantitative relations are readily computed by mathematical formulae which treat the induction motor as a modified transformer. Such treatment is apt to be considered as highly artificial. Most of the results obtained by the transformer treatment may be obtained by considering the alternating motor as a variety of the general motor and as closely akin to the more familiar direct current motor.

In the induction motor there are two or more sets of field coils separated in space by a definite number of degrees and

carrying currents which are a more or less definite number of time-degrees apart. In the case of two-phase or quarter-phase motors the currents are 90 time-degrees apart, and the coils are 90 space-degrees apart; when as is usual, there are more than one pair of poles in the motor in order to reduce the number of revolutions, the angular distance from one north pole to the next north pole is considered as 360 electrical degrees. In case of three-phase motors the sets of coil and the currents are 120 electrical degrees apart. In the case of single-phase induction motors the coils and the currents are somewhat less than 90 electrical degrees apart. Any of these combinations of coils and currents will produce a revolving magnetic field of approximately constant strength, as was discussed under the law of combination of forces, the fifth law mentioned in the early part of this paper.

For convenience, consider a motor in which the rotor is the armature or secondary, and in which the stator carries the coils connected with the line; also assume for convenience that there is only one set of coils and one pair of poles. The effect of currents displaced in time and space in the field or primary winding, is to create a magnetic field which revolves with the same frequency as that of the applied currents. If the iron core of the rotor has two projecting poles, then after once being started, it will be pulled around at the same speed as the revolving field, and it will be a synchronous motor.

If the magnetic circuit of the rotor is practically uniform in all directions, the revolving magnetic field can revolve through the rotor without causing much of any magnetic drag except a weak one due to hysteresis, if for the moment the effect of induced currents be neglected. Such a hysteresis motor is illustrated by a rotor built up of smooth discs of sheet iron well insulated.

Another factor, however, enters into the operation of the motor with revolving magnetic field. If the magnetic field revolves faster than the rotor, there will be induced in the rotor electromotive forces which are proportional to the strength of the magnetic field, to the length of any electrical conductor in that field and to the relative velocity between the field and the conductor. Then if there is a closed electric circuit, this electromotive force will cause current to flow, and this current reacts upon the magnetic field and causes torque. The problem is to direct the currents in the various conducting paths so that they will pass in the proper direction through the magnetic field and all pull together. The essential features therefore of the induction motor are a rotating magnetic field.

and induced currents which react upon it. If at any instant the distribution of the magnetic field is sinusoidal, the electromotive forces induced by the various parts of the field will also be sinusoidal and consequently the currents in the various paths at any instant will be sinusoidal; that is, at any given instant one conductor will carry a large current, those on either side will carry currents successively smaller and smaller until certain conductors carry no current at all; beyond these the currents will be in the opposite direction getting larger and larger until at a point 180 electrical degrees from the starting point the current will be of maximum value and in the opposite direction.

It will readily be seen that the relative velocity between the revolving magnetic field and the rotor is greatest when the rotor is at standstill, and that if the rotor could run at synchronous speed there would be no RELATIVE motion between the field and the rotor. Therefore, the electromotive forces and consequently the currents in the rotor will be greatest when the rotor is at standstill, and will be zero at synchronism. Therefore, if the currents in the rotor occupy the same relative positions with reference to the revolving field, the torque will be greatest when the rotor is at standstill and will be zero should the rotor revolve at sychronous speed.

The electromotive force in any conductor in the rotor changes direction every time the direction of the magnetic field changes. Thus when the rotor is at standstill, the induced current has the same frequency as the revolving field which is the same as that of the current from the line. Should the motor come up to full synchronous speed, there would be no relative speed between field and rotor and the frequency of the induced current would be zero. Thus the higher the speed of the rotor the lower is the frequency of the current in the rotor.

Now the currents in the rotor set up more or less of magnetic field of their own, and this involves self induction and counter electromotive force. The counter electromotive force depends not only upon the magnetic field but also upon the frequency. The induced current lags behind the electromotive force by an amount depending on the relative values of ohmic resistance drop and counter electromotive force. Consequently, at low speed the current lags greatly behind the electromotive force and is therefore greatly displaced from the main magnetic field. By inserting resistance in the electric circuits in the rotor, the currents are brought more nearly into phase with the magnetism, and brought into phase more than

the current is reduced. Consequently, introducing resistance into the secondary circuit increases the starting torque.

As the rotor comes up to speed, the relative motion between the armature and the revolving magnetic field becomes less, and therefore both the frequency and the amount of the electromotive forces induced in the armature become less. The reduction in the secondary frequency lessens the reactance and consequently the impedance of the secondary circuit, so that not only does a given electromotive force cause a larger current, but also that current is more nearly in phase with the electromotive force, and therefore more nearly in phase with the magnetic field, and thus is more effective in producing torque. Thus it follows that, within certain limits which are derivable mathematically or experimentally, the lessening of the induced electromotive force as the motor comes up to speed is more than balanced by the smaller impedance and the better location of the induced current. Thus as a motor comes up to speed, the torque increases to a certain critical speed, after which it gradually reduces toward zero as the speed approaches synchronism.

Any induction motor will run on single-phase current if some means be provided for bringing it up to speed. It happens not infrequently that a motor running on a two-phase or three-phase circuit will continue to operate even after a fuse has blown or the circuits are otherwise interrupted so that only single-phase current is supplied; if such motors, however, are stopped by the interruption of the remaining single-phase current, they usually will not start again unless supplied with polyphase current. Similarly, some of the single-phase motors, such as the Wagner or Century, have special starting devices which are in use only during the starting period, the motors running normally as ordinary induction motors.

The operation of an induction motor when supplied only with single-phase current, may be explained in several ways. Perhaps the simplest is to consider the action of two secondary or amature coils, A and B, which at a given instant occupy complementary positions with reference to one of the magnetic poles. As noted previously, the magnetic field due to coils carrying single-phase current does not rotate in space but simply rises and falls first in one direction and then in the opposite direction. As the armature revolves, one of the coils, say A, moves toward a position where it includes more magnetic lines from the pole, while coil B in the complementary position moves so as to exclude magnetic lines of force. When field current is increasing, coil A will have an induced

electromotive force larger than that in coil B, since in A the rate of change of lines enclosed equals the sum of the rate of change of the field strength and that due to the motion of the coil in the field, while in coil B the rate of change equals their difference. Although the current in each coil lags behind the electromotive force, both currents will exert a pull against the magnetic field, but coil A will pull harder than coil B. When the field current is decreasing, the flux through coil B will change more rapidly than that through coil A, but the direction of the induced current is reversed, so that coil B now pulls in the same direction that coil A did before. Therefore the net effect of both the rising and the falling magnetic field is to pull the armature in the direction in which it was moving, and a single-phase induction motor (with only one set of field coils and without shading coils or similar devices) will run in either direction after being started.

Another way to think of the single-phase induction motor, is to consider that a revolving magnetic field exists, either through the combined action of the supplied and the induced currents, or by the resolution of the single-phase field into two fields rotating in opposite directions. Taking the latter view, the currents in the primary windings of a single-phase induction motor may be considered as setting up a magnetic field which is stationary in position and which varies harmonically in strength. Such a field would also be produced by the resultant action of, and may be considered as resolved into, two component fields of constant strength and rotating in opposite directions. Each of the two rotating fields may be considered as causing currents in the armature coils, which currents exert torque in the direction of the inducing rotating field. When the armature is at a standstill, the two rotating fields cause equal currents and equal torques in opposite directions, and there is no net starting torque; but if the armature is started in either direction, the relative motion between it and the field rotating in that direction becomes less and the torque in that direction becomes greater, as previously discussed; on the other hand, the relative speed between the armature and the field which rotates in the opposite direction, becomes greater and the torque in that direction becomes less; consequently the net torque is in the direction in which the armature was started, and increase with the speed up to a certain maximum which may be determined experimentally or mathematically.

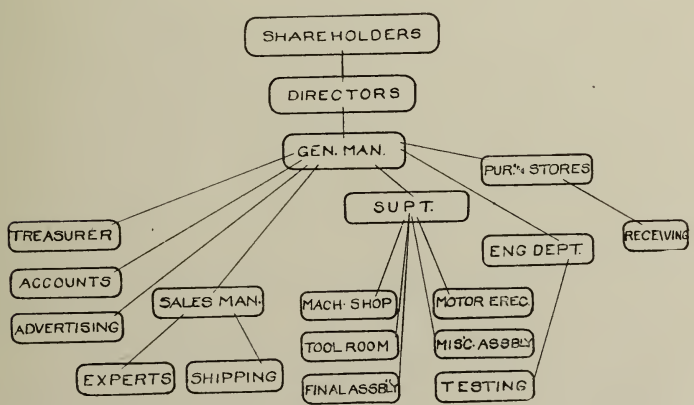
By placing copper loops or "shading coils" about corresponding parts of each pole of a single-phase induction motor, it is possible to secure a magnetic field which rotates

in one direction, even when the armature is stationary. As the magnetic field rises or falls, induced currents flow through the coils which surround part of the pole; these currents resist changes in the enclosed magnetic flux, and so retard both the rise and the fall of the magnetic field; the result is that the magnetic field through the shading coils lags somewhat behind that through the unshaded part of the poles. This results in the equivalent of a revolving although unsymmetrical magnetic field. Such shading coils are frequently used on fan motors for obtaining the necessary torque at starting.

AN UP-TO-DATE SHOP

J. V. Martenis, Assistant Professor of Mechanical Engineering

Present day methods now in use in our best machine shops are far in advance of those used in past years and the rapid strides that are being made in machine building, for turning out more work makes it difficult for shops to keep up to date in their methods and equipment. The writer was granted the privilege of thoroly inspecting one of our up-to-date shops in Minneapolis, and of obtaining information relative to their methods of manufacture, of shop management systems of cost keeping, records of materials in the rough, and finished, etc., which are worth careful study as they represent the results of much investigation and experimentation. It is not the purpose of this article, however, to go into all of these details as much as their merit would justify. The product of the shop visited is the gas traction engine. The shop management is arranged in the manner shown by the accompanying diagram of shop organization, a copy of which could be found at the desk of each shop foreman. The keynote is that of co-operation, and the get-to-gether spirit is further fostered by fortnightly meetings of the manager, superintendents and foremen on which occasions there are discussions of shop methods, complaints of lack of co-operation are lodged, and ways and means of bettering conditions are gone into, all of which tend toward a better working basis. The esprit de corps is excellent.



—ORGANIZATION—

The drafting room is well ventilated and lighted and equipped with universal drafting machines. The shop drawings are numbered consecutively and each piece carries a pattern number whether the piece is a casting or not. All of the work is done according to drawing. Whenever a correction is issued on any piece a new drawing is made and consequently takes a new number. The object of this is to mimimize the possibility of error when a replacement is required for an older engine.

The purchasing department has formulated a set of report blanks one of which gives a record of pieces on hand, also the number of pieces received during the week. This report is on file at the foundry and machine shop and acts as a guide in showing what parts should be given preference in case of rush orders. Another report form gives the weekly cost of machining and assembling engines, and also enables the management to keep in close touch with the cost of production for each individual piece. A diagram is plotted from these costs which shows graphically the fluctuation in production cost for the whole year. By a systematic investigation, the cost of machining has been reduced 25 per cent of what it was one year ago. The cost is obtained by means of orders which carry every piece made in the shop. In addition to this there are orders for assembling. Requisitions for complete parts are priced from the separate orders, thus obtaining the price of the assembled parts, such as the transmission, the differential, the motor, etc. The erecting requisition calls for one each of all the assembled parts to build the engine complete. The overhead charge which includes the salaries of office help, shop expense, oil, waste and miscellaneous expenses is covered in the cost system by adding an overhead cost to each single order. This cost system has the important advantage in this, that each of the orders carries the actual cost of production and insures an accurate statement of profits, which is usually problematical where a system of estimating is resorted to.

The raw materials received are carefully checked and recorded so that each week the balance sheet gives the quantities of material on hand; at the same time a record is kept of the finished pieces and these are likewise entered on stock sheets. When a job is given to a workman a number is placed on the job and a record is made by a calculagraph of the elapsed time spent on that job. In looking over the records it was found that it required 15,065 minutes to machine all the parts that go into one engine. It had formerly been the custom to issue

View of Machine Shop

supplies from the store room for the building of the engines, and these supplies were drawn by requisition on the store keeper. It was found when the rate of production increased that the amount of time lost by the workmen waiting in line for the supplies involved a serious loss and that other means should be devised, to obviate this condition. As a result of this at the present time there are placed in the erecting shop portable cabinets containing complete supplies and equipment for nine engines, which constitutes the output for one week, and in the case where bolts and other parts to be assembled lie in the underneath portion of the engine a form of low truck mounted on castors is used.

The machine shop has many interesting features and it might be well to note some of these. The power drive is what is known as the group system. The motors vary from 15 H. P. to 20 H. P. One motor drives two radial drill presses, two planers, one grinder, and one oil separator; one motor takes care of the crank grinder; one motor drives two radial drill presses, two milling machines, two lathes, two heavy duty drills, four saws, two buffing wheels, one centering machine, and a bench drill; one motor drives one hub machine, two boring mills, five drill presses, and three lathes; one motor drives four lathes, three turret lathes, 20 inch shaper, two tool grinders, and one bench drill; one motor drives two automatic lathes, one turret lathe, one Acme automatic lathe, one cold saw and one drill.

The Acme automatic lathe was turning out $\frac{5}{8}''$x5$''$ turned bolts at the rate of 450 to 500 in every ten hours; the material used was 1 inch square bars of mild steel. Four operations were being performed simultaneously.

The pistons are bored out and faced on a turret lathe and then transferred to another turret lathe where they are turned to size and faced on the compression end, and the ring grooves cut, all in one setting. The work is held on a mandrel and requires 30 minutes time in the second turret lathe. The pistons are then taken to a third lathe where they are put in a chuck and the holes bored out for the wrist pins. The wrist pins are made of 2 inch mild steel turned up on a turret lathe and drilled out by what the shop men call a tube drill, that is, small brass tubes are carried in the grooves of the drill supplying oil at the drill point. The pins are grooved transversely and then case hardened, and finally ground down to the finished size, the amount of grinding being 2-100 of an inch.

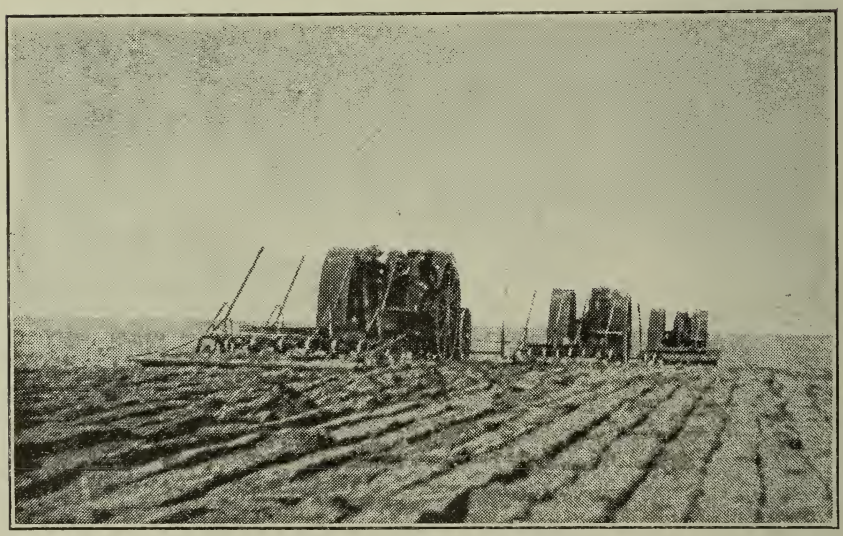
View of Assembly Room

The rods are drop forged and require 16 operations from the rough state until finished for use. First they are drilled for the wrist pin and reamed, drilled for babbitt on the crank pin end, milled and drilled for bolts, cap sawed off on crank pin end, cap and rod milled, male and female, cap is then assembled on rod and drilled for babbitt, then drilled for clinch pin, and finally babbitted, reamed and faced.

The cylinder castings are faced and bored in a chuck on the boring mill, and as we may well note here practically all of the work is chucked which not only saves largely in time but also ensures correctness in the finish of the work.

The piston rings are turned eccentric then cut at 45° angle, sprung together and then turned again. They are ground to size on the sides with a magnetic chuck grinder.

The crank shafts are drop forged. They are centered and rough turned at ends. The shaft is then put in the chuck driver for turning the crank pins, which are also ground to size.



In Action

The engine motor used is the development of experiment and experience and its performance must reach a certain power development before it leaves the shop. The shafts and rods are connected and adjusted and are given a trial run by belt for four hours. The motor parts are then assembled and taken to the test department where the motor is given a run by belt for 8 hours, in oil, after which it is tested by a Prony

brake, first being given a run of 6 hours light and then a run of 6 hours loaded. The motor must develop 55 H. P. before it leaves the shop. A Schultz 4 cylinder manograph is used to guide in determining valve setting, etc., and enables them to secure the most satisfactory performance from the motors. After testing, the motor is mounted on its frame and running gear and an outside test is made in climbing a steep incline, and also drawing load.

A school has been established for the purpose of instructing purchasers how to run the motor and also how to overcome obstacles which may at times interfere with the smooth running of the engine. The corps of instructors are selected from the best men in the shops.

Here in the northwest where farming is carried on in a large way, traction engines are almost indispensable. The gas engine as a motive power is a development tending toward better economy and lighter weight in the tractor and is especially adapted for service where water is either scarce of unsuitable for steaming purposes.

ASPECTS OF THE PREMIUM AND BONUS SYSTEMS

Stanley G. Harwood, M. E. '08

Any system which helps or induces men to work more efficiently is to be welcomed as a step in the right direction. That premium and bonus systems tend to increase the output of individual men has been demonstrated by the experience of several large and important companies.

The premium and bonus systems as their name denote, are methods for paying labor, in which a reward is given for increased output. The words mean practically the same thing and it will be best to use them as applying to the systems which have as their basis the plans laid down by the original exponents of the so-called Premium and Bonus systems.

In the premium plan as outlined by Mr. Halsey, the time ordinarily required to do a piece of work is ascertained and the men are offered, besides their day pay, a certain amount for each hour which they save by decreasing the time per piece. It is a system which is easy of application, no elaborate explanations to the men being necessary,.. in fact, requiring nothing of the men, but offering them a present if they will exert themselves.

The basis of compensation is extremely simple and may be readily found,—it being merely the time which has been used previously. This is one of the principal arguments of the believers in the plan and is the invariable argument of the "stand-patters," and the man in a rut, who would rather use a poor system and let things take their course than by a scientific investigation of the truth, arrive at a basis which is right and which obviates all further difficulty. Such as Mr. Frederick Taylor have shown how erroneous an attitude is. Let us see how nearly such a scheme approximates a true basis, and see whether or no it is a basis at all. Experience tells us that the time a man spends on a piece is not a measure of his capacity or even of the average man's capactiy which is used in the day's work plan as a basis of payment. We can also see that the remuneration which the laboring man receives for his ordinary day's work is not necessarily the amount which, morally, he should receive, since we have no adequate means of determining the intrinsic value of his work to the world. We must arrive at the conclusion that a system which uses the ordinary day's work as a basis of payment, is a makeshift, which is only good for one shop at best. By carrying on the

investigation further, we see that the work accomplished in a day, depends primarily, on the policy of the management, as to the requirements made of their men. The standard of effort begins with the superintendent and extends down,— depending in the last analysis on the diligence of each individual man and his relative efficiency as compared with the average worker. Over all and all pervading is the question of system, —is each unit exerting his efforts in such a way that the maximum of useful work is produced by those efforts? Under the ordinary day's work, we cannot find this out. It is generally conceded that when the foundation of any system is wrong, the system is merely a means by which we may improve on a bad system and the worse the original, the greater our apparent or percentage gain.

By my last paragraph I do not mean to state that the premium system is utterly devoid of good,—because is has been inaugurated and sucessfully used in several notable instances, and is spoken of favorably by such men as Mr. Wm. Kent,—but what I do mean to state is that since its basis is wrong, it cannot be the best system, or the system, which will, in the end, prevail. The premium system has its field, tho a limited one, and may be used as a stepping stone to better methods. Under it, the men will surely increase their output, they being pleased and benefited accordingly, and the employer will be benefited to an even greater degree. To analyse this grain specifically we shall suppose that Smith bores ten pulleys in a day, receiving 20 cents per operation. Mr. Jefferson, proprietor, offers Smith half the time-cost on each additional pulley bored. Smith is soon able to turn out 20 a day and receives $1.00 above his former pay. Now, Mr. Jefferson, in order to accomplish this end under the old day's work system, would have been obliged to put in a new lathe and to hire another man. We will consider that the overhead charges for each man and equipment are $2.00. Now we see that Mr. Jefferson saved

Overhead charges	$2.00
Wages	1.00
Total gain	3.00

Mr. Jefferson would be a very unreasonable man if he were not pleased by such an outcome, but an unprejudiced thinker would hardly be reconciled as to the fairness of a system under which one man took 70 per cent of the saving which another man effected. Someone, at this juncture will bring up the statement that the man who turned out ten pieces when he

could turn out twenty, was not giving a fair return for his wages. This statement will bear argument, but in the final judgement we shall find that this is a question which we cannot decide. Then only solution to the question at present is, to ascertain from economic conditions, the amount of relative benefit which is obtained from the product of the labor of the man and remunerate him accordingly. A solution to the question can only be arrived at in a round about way. In practice the law of supply and demand decides what an article is worth, the capitalist decides as far as possible what part of the total cost of production labor shall receive, and the average day's work of the thousands of men doing that class of work decides what a day's work shall be. Now if the wages per piece, so decided, is a fair one and if the man in question is doing this average amount of work,—then he is giving a fair exchange and if, by his own efforts, he increases his output, he is entitled to receive the gain which ensues and any system which gives him three-sevenths of that gain is not a fair one.

From the previous discussion, it would appear that payment for time spent is not a true or universally applicable basis. It is an aid to obtaining the data for a "commercially" perfect basis that the premium system may be used. Under the stimulus of more pay for more product the workman will reach his maximum output, and under such conditions the rate fixer can find the time which a piece of work should take, and the data may then be applied to the piece work system.

As a process of evolution the premium plan offers possibilities. In the piece work system, the rates are set (ideally according to what the work is worth),—practically by what the manager considers to be best for himself. Now these rates are often less than day rates and the workmen demur, and argue that they cannot make day rates under such a system and, in some cases, believe it. The premium plan offers no such objections and shows them that they can increase their output. From the premium plan it is a very easy step to piece-work.

In some instances, such as the case in small shops, where no regular line is manufactured and in which piece work would not well apply, the proprietor may increase his profits and those of the men by offering a certain amount for each hour saved from the previous time required.

In looking back over the various aspects of the premium plan we find the dominant features to be:

1. The basis of rate fixing is not a scientific one.

2. Increases the money gain of both employer and employee.

3. Discriminates in favor of the employer.

4. It is paternal in its application and effect.

The bonus system is an emanation of the mind of Mr. Gantt. It is a system in which the workman is paid a bonus for doing the work in a time specified by an estimator who endeavors to fix the time at such an amount that the workman will be obliged to work to his full capacity. It has some good points and some equally faulty ones. By this method, the workman is given a chromo for doing the work in the time set. He must do the work in this time or he will not receive his reward and if he can do it in less time, I hardly think that the rate setter would learn of it. Even if one man could do it in less time, perhaps another man who strove just as hard would fail to even make good on the time set. This shows one of the worst phases of the system, that is, it makes no differentiation of the individual capacities of the men, and since such differences of capacity do exist, a system which does not take this element into consideration, is necessarily a narrow one. Moreover, whether or not, the workmen are paid fairly depends on conditions. If the time is so set that the wages paid without the premium, are such as economic conditions create, it is fair and the workman by exerting himself to obtain a premium is doing extra work for extra pay. On the other hand, if he does not try for the premium but takes as long a time as he likes, unless some provision be made or the man be discharged, the employer is not receiving his due. Such being the case, the system would appear to be very rigid and any claims for automatic regulation to be unfounded,—the only points effected being the extremes. Moreover, this system offers a most violent transition from the day system, being a jump from below capacity to maximum capacity. This objection can only by overcome by lengthy explanations on the part of the employer.

Mr. Gantt has included in his plan, several auxilliary systems which add greatly to its efficacy but do not belong exclusively to any one system. He uses the Taylor elemental rate fixing system and makes, for each piece of work, an instruction card which gives, the best known method for doing each piece of work, with feed and depth of cut and the time required for both elemental and whole operations. These aids to production are excellent and apply to any system and almost any class of work, and therefore, do not enter into a discussion of bonus system in the abstract.

In review we see that the dominant features of the bonus system are:—

1. Of itself it merely offers a chromo for obeying orders.
2. It is of great benefit to the employer.
3. It offers a violent transition from the day work system.
4. It lacks flexibility, in that there is no differentiation in individual capacity.

In treating the premium and bonus systems I have not endeavored to prove that any one system is best but to look at the problem from an academic stand-point. Being prejudiced, in favor of neither workman or employer, I have tried to apply tests to the systems which would show whether or no they were fair and could be so applied as to bring about amicable relations between two naturally antagonistic elements, believing that,—in the end, that system would prevail which proved to be fair to all concerned.

AVIATION

C. H. Chalmers, E. E. '94.

Lecture before the Engineers Society, University of Minnesota

Few people realize the amazing strides being made almost daily in mechanical flight. How many people know that aeroplanes have been in the air for eight or nine hours at a time and that two mile flights with 12 people on board have been made?

It is the usual thing in an address of this character to begin with a reference to Greek mythology, then pass to a brief review of some very interesting experiments made in the middle ages or soon after. All of this is interesting and would lead us to the conclusion that had the men of those days been in the possession of any source of power of light weight similar to our modern automobile engines (not to mention the modern three pound per H. P. engines now available for the aviator), the problem of mechanical flight would have been solved long ago. The next thing on the regular program is to discuss in detail the work of the Mongolfer Bros. of France and from there lead up to a full and elaborate discussion of modern dirigible balloons as examplified in the war balloons of the governments of Grance, Germany, England and the United States. In this field the Germans lead and their great ship Zeppelin is unequalled.

I, however, wish to pass all this by with no more attention than I have just given it, and in its place, indulge in a little sentimental history about the late Samuel Pierpoint Langly, Secretary of the Smithsonian Institution at Washington D. C.

The development of those inventions which effect mightily human progress and human mastery over the forces of nature is often coupled with pathetic incidents. In this connection mechanical flight has a bit of history keenly interesting in the light of the lively interest taken in the subject at the present time thruout the civilized world.

The steamship and the aeroplane have such a uniquely similar story in this respect that one can scarcely tell the former without at the same time also telling the latter.

Just about a hundred years ago, Robert Fulton invented and built the first large steamboat, and in a short time the ocean steamer—gradually evolved into our magnificient ocean liners of today—took its place as one of the wonders of our age and is well to the fore in its benificent effects on the human

race in aiding man to master the elements and proceed as he pleases over nearly two-thirds of the surface of the globe. But before Fulton was John Fitch. John Fitch was the real father of the steamboat and had the honor of displaying his boat to Geo. Washington and the members of Congress Aug. 22, 1787, or 20 years before Fulton came out with his larger but not different steamboat. But John Fitch never in his life got the recognition due him, and in 1798 died of a broken heart—a suicide, and laughed at as a lunatic thus ending one of the saddest lives in all history.

Strangely similar to the above story is the recent history of the dynamic flier. Somehow history surely does repeat itself. Just 100 years after Fitch or in 1887 Samuel P. Langly started his first experiments which later lead to the building of his aerodrome. So far as I can learn after careful study Langly was the first to successfully fly a heavier than air machine of any proportions.

So great was his success that the Board of Ordinance and Fortifications of the U. S. War Dept. allotted $50,000 for him to construct his man carrying machine. The machine was built, but unfortunately was broken in the launching and to this day has never had a fair chance to fly. The money was all spent. Langly could get no more. The whole world laughed and shouted, Failure! failure! another Darius Green! A few years later Langly died of a broken heart and is only now beginning to get some of the recognition he so richly deserves.

Twenty years later came the Wrights like Fulton to win the praise and recognition of which Langly justly deserves so large a share. However the speaker yields to no one in his admiration of the brothers Wright for their contribution to aerial flights, but yet I do most earnestly plead for the dead hero whose painstaking labors are the first great achievement in this new field. Mr. Manly who was Langly's assistant and who has followed the modern development of the aeroplane, and who is more or less an authority on the subject gives it as his present opinion that the aerodrome would today if repaired and carefully launched, make a successful flight.

In our treatment of the subject we will omit the lighter than air machines for the reasons that public interest in them is waning and because the heavier than air type is so much more interesting, and for the additional reason that in one lecture there is no time available for that branch after even a most brief presentation of dynamic flight.

If we except the work of the Wrights from 1903 to 1905, we may say the real history of power driven aeroplanes began Dec. 23rd, 1907. It was then that the whole civilized world got its first real thrill, and really felt that a problem of which the race had dreamed for 5000 years was about to be solved. On that memorable day the Signal Corps of the U. S. Army put out its invitation for bids on flying machines. Even tho this was but 3 years ago, it is difficult now to fully appreciate the doubt and amazement of the world at this action on the part of our government. In order to take you back those three years and make you appreciate public opinion at that time I can do no better than quote an editorial appearing in the New York Globe a few days after the appearance of the Government specifications. I quote the editorial as follows:

"One might be inclined to assume from the following announcement the United States army is asking bids for a military airship that the era of practical human flight had arrived, or at least that the government had seriously taken up the problem of developing this means of travel. A very brief examination of the conditions imposed and the reward offered for successful bidders suffices, however, to prove this assumption a delusion."

"A machine such as described in the Signal Corps specification would record the solution of all the difficulties in the way of the heavier-than-air airships, and, in fact, finally give mankind almost as complete control of the air as it now has of the land and water. It would be worth to the world almost any number of millions of dollars, would certainly revolutionize warfare and possibly the transportation of passengers; would open to easy access regions hitherto inaccessible except to the most daring pioneers, and would in short, be probably the most epoch-making invention in the history of civilization.

"Nothing in anyway approaching such a machine has ever been constructed (the Wright Brothers claims still await public confirmation), and the man who has achieved such a success would have, or at least should have, no need of competing in a contest where the succesful bidder might be given his trial because his offer was a few hundred or thousand dollars lower than that of some one else. If there is any possibility that such an airship is within measurable distance of perfection, any government could well afford to provide its inventor with unlimited resources and promise him a prize, in case of success, running into the millions."

The following are the specifications.

SIGNAL CORPS SPECIFICATION, NO. 486.

ADVERTISEMENT AND SPECIFICATION FOR A HEAVIER-THAN-AIR FLYING MACHINE.

To the Public:

Sealed proposals, in duplicate, will be received at this office until 12 o'clock noon on February 1, 1908, on behalf of the Board of Ordnance and Fortification for furnishing the Signal Corps with a heavier-than-air flying machine. All proposals received will be turned over to the Board of Ordnance and Fortification at its first meeting after February 1 for its official action.

Persons wishing to submit proposals under this specification can obtain the necessary forms and envelopes by application to the Chief Signal Officer, United States Army, War Department, Washington, D. C. The United States reserves the right to reject any and all proposals.

Unless the bidders are also the manufacturers of the flying machine they must state the name and place of the maker.

Preliminary.—This specification covers the construction of a flying machine supported entirely by the dynamic reaction of the atmosphere and having no gas bag.

Acceptance.—The flying machine will be accepted only after a successful trial flight, during which it will comply with all requirements of this specification. No payments on account will be made until after the trial flight and acceptance.

Inspection.—The Government reserves the right to inspect any and all processes of manufacture.

GENERAL REQUIREMENTS

The general dimensions of the flying machine will be determined by the manufacturer, subject to the following conditions:

1. Bidders must submit with their proposals the following:
   - (a) Drawings to scale showing the general dimensions and shape of the flying machine which they propose to build under this specification.
   - (b) Statement of the speed for which it is designed.
   - (c) Statement of the total surface area of the supporting planes.
   - (d) Statement of the total weight.
   - (e) Description of the engine which will be used for motive power.

(f) The material of which the frame, planes, and propellers will be constructed. Plans received will not be shown to other bidders.

2. It is desirable that the flying machine should be designed so that it may be quickly and easily assembled and taken apart and packed for transportation in army wagons. It should be capable of being assembled and put in operating condition in about one hour.

3. The flying machine must be designed to carry two persons having a combined weight of about 350 pounds, also sufficient fuel for a flight of 125 miles.

4. The flying machine should be designed to have a speed of at least forty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight, according to the following scale:

40 miles per hour, 100 per cent.
39 miles per hour, 90 per cent.
38 miles per hour, 80 per cent.
37 miles per hour, 70 per cent.
36 miles per hour, 60 per cent.
Less than 36 miles per hour rejected.
41 miles per hour, 110 per cent.
42 miles per hour, 120 per cent.
43 miles per hour, 130 per cent.
44 miles per hour, 140 per cent.

5. The speed accomplished during the trial flight will be determined by taking an average of the time over a measured course of more than five miles, against and with the wind. The time will be taken by a flying start, passing the starting point at full speed at both ends of the course. The test subject to such additional details as the Chief Signal Officer of the Army may prescribe at the time.

6. Before acceptance a trial endurance flight will be required of at least one hour during which time the flying machine must remain continuously in the air without landing. It shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight. During this trial flight of one hour it must be steered in all directions without difficulty and at all times under perfect control and equilibrium.

7. Three trials will be allowed for speed as provided for in paragraphs 4 and 5. Three trials for endurance as provided for in paragraph 6, and both tests must be completed within

a period of thirty days from the date of delivery. The expense of the tests to be borne by the manufacturer. The place of delivery to the Government and trial flights will be at Fort Myer, Virginia.

8. It should be so designed as to ascend in any country which may be encountered in field service. The starting device must be simple and transportable. It should also land in a field without requiring a specially prepared spot and without damaging its structure.

9. It should be provided with some device to permit of a safe descent in case of an accident to the propelling machinery.

10. It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time.

11. Bidders must furnish evidence that the Government of the United States has the lawful right to use all patented devices or appurtenances which may be a part of the flying machine, and that the manufacturers of the flying machine are authorized to convey the same to the Government. This refers to the unrestricted right to use the flying machine sold to the Government, but does not contemplate the exclusive purchase of patent rights for duplicating the flying machine.

12. Bidders will be required to furnish with their proposal a certified check amounting to ten per cent of the price stated for the 40-mile speed. Upon making the award for this flying machine these certified checks will be returned to the bidders, and the successful bidder will be required to furnish a bond, according to Army Regulations, of the amount equal to the price stated for the 40-mile speed.

13. The price quoted in proposals must be understood to include the instruction of two men in the handling and operation of this flying machine. No extra charge for this service will be allowed.

14. Bidders must state the time which will be required for delivery after receipt of order.

JAMES ALLEN,

Brigadier General, Chief Signal Officer of the Army.

SIGNAL OFFICE,

WASHINGTON, D. C., *December 23, 1907.*

A little later the U. S. War Dept. sent out the following additional notice:

War Department
Signal Office

January 14th, 1908

NOTICE TO BIDDERS

The action of the Board of Ordnance and Fortification in a meeting January 2nd, authorizes the Chief Signal Officer of the Army to modify Specification No. 486, for a heavier-than-air flying machine, so that a bidder may reserve as confidential any features of his machine which he wishes kept secret. In describing the flying machine, features which are omitted for this reason should be referred to with a remark to the above effect.

JAMES ALLEN,
Brigadger General, Chief Signal Officer of the Army.

The Engineering News for Feb. 13th, 1909, contained the following brief announcement:

FLYING MACHINE. WASHINGTON, D. C.

"The Secretary of War has approved the recommendations of the Board of Ordnance and Fortifications that bids for furnishing a heavier-than-air flying machine to the United States Government be accepted as follows: J. F. Scott, Chicago, Ill., $1,000.00, 185 days; A. M. Herring, New York, $20,000.00, 180 days; Wright Bros., Dayton, Ohio, $25,000.00, 200 days. In all 41 bids were received; three were the only ones that complied with the requirements of the government. It was part of the agreement in issuing the call for bids that none of the particulars of the bids were to be given out but retained as confidential."

Aeronautics, the best Aeronautical journal in the world, in its March issue in 1908 contained the following editorial:

"One fails to realize the proposition. The magnitude of what is too close we are never able to measure. The results of what is really an event we are unable to predict. We had boats and it does not seem so great to have them self-propelled. We had beast-drawn vehicles and they were made to move of themselves. But to conceive the wonderfulness of locomotion in air———.

"When steam was applied to means already at hand, five continents were made into one and the earth shrunk under its rule. The aims of lands and forms of commerce,

human occupations and communications, the manner of war and the structure of the social body were changed. The conquest of the earth was achieved by man. Everything was changed, overthrown, enlarged and created anew. What was not altered?

"Now we have invented a new means. To consider the future is to become lost in a maze of possibilities. To predict is futile.

"When the specifications were made public, few of those practical men whose achievements have made their opinions weighty, were optimistic enough to imagine that the requirements could be met by anyone. The acceptance of the bids proves three men either foolhardy or the rest of us way behind the times. With all our hearts we hope the latter may, in this instance, be found the case. A failure on the trial day would be a terrible blow to aeronautical progress in America, and we would say, better had we gone more slowly."

In September, 1908, Mr. Orville Wright had practically completed the demonstrations of the ability of his machine to fulfill the government specifications when an unfortunate accident injured him seriously, killed his companion, Lieutenant Selfridge, and smashed the machine. The machine was later accepted by the United States government and so in the first six months of 1908 we have the first great epoch in dynamic flight.

So far I have treated the subject in a more or less popular manner, feeling such to be a proper preliminary to a more technical and scientific discussion of the subject before an engineering society such as this. At this point, however, I wish to take up those considerations usually omitted in popular talks but which seem to me should prove of interest to a body of young men in training for the engineering profession.

When an engineer approaches the subject of AVIATION he naturally turns to the fundamental formulae for air pressures, lift, drift, normal pressures etc. These you will find in the Enc. Britannica over Mr. Chanute's initials. They are as follows:

(1) Wind force, $F = k\ V^2$.

(2) Pressure, $P = k\ V^2\ S$.

(3) Velocity, $V = \sqrt{\frac{W}{k\ S\ n \cos a}}$

(4) Surface, S, varies as $1/V^2$.

(5) Normal, $N = k\ S\ V^2\ n$
(6) Lift, $L = k\ S\ V^2\ n \cos a.$
(7) Weight, $W = L = N \cos a.$
(8) Drift, $D = k\ S\ V^2\ n \sin a.$

The values of n cos a are different with different angles of incidence and also vary with the character of the surface. For plane surfaces the values given by Chanute are .035 for one degree and .173 for 5 degrees. The value of n cos a for curved surfaces, where the concavity is one to twelve, is .434 for one degree and .647 for 5 degrees. Mr. Horatio Phillips after a most elaborate series of experiments proved that the lift on suitably curved surfaces is 2.74 times that of plane surfaces while the drift remains the same.

The values of k and likewise those of n cos a need more study. On this subject there are numerous aerodynamic data for low velocities, and also for very high velocities, but such data are incomplete for the range of velocities here considered. The work of S. P. Langly is very largely the only reliable experimental basis. Langly's velocities were low compared with modern aeroplane speeds. Whether the resistance of the air varies with the square of the velocity at speeds between 40 and 75 miles per hour needs to be looked into. For example, in the enormous velocities attained by modern artillery, where bodies weighing a ton or more, are hurled through the air at 2,000 feet per second, it is known that the physical phenomena become entirely different in nature from those found when dealing with moderate velocities such as are met in transportation devices. In the expression for the retardation of oblong projectiles the velocity enters with an exponent n whose accepted value is 1.55 for velocities of 2,600 feet per second or more, (1,773 miles per hour or more), while its value is 2 for velocities of 790 feet per second or less, (592 miles per hour or less.) The 16 inch guns of our navy use a 2,400 lb. projectile having a muzzle velocity of 2,150 feet per second or 1,465 miles per hour, giving them a range of nine miles with a elevation of 15 degrees. These great guns have a range of 15 or 20 miles and the velocity of the projectile and its momentum are so great that the wind has little or no effect. The shapes of these heavier-than-air flying machines are figures of revolution and the longitudinal and lateral stability are maintained by the rotary motion imparted by the rifling of the gun barrel. Such machines are 5,000 or 6,000 times heavier than air and travel at speeds away beyond anything else created by man. These projectile air machines are 2½ times

heavier than a Wright biplane and travel at a velocity about 36 times as great.

It thus appears that the resistance of the air to bodies passing through it, is in reality a complicated function of the velocity and the best that can be said is that this function is a constant quantity only within certain limited ranges.

When we come to the general subject of heavier-than-air machines we find several natural subdivisions depending upon the principle of operation involved. Among these may be mentioned the aeroplane, orthopter, helicopter etc. Only the aeroplane has so far been developed to a man carrying proposition. There are many types and makes of aeroplanes more or less developed and a brief description of one or two may be of interest. A description of the Wright machine which fulfilled the government specification is as follows:

The aeroplane has two superposed main surfaces 6 feet apart with a spread of 40 feet, and a distance of 6½ feet from front to rear. The area of this double supporting surface is 500 square feet. The planes are so made that their extremities can be warped at the will of the operator. A horizontal rudder of two superposed plane surfaces about 15 feet long and 3 feet wide is placed in front of the main surfaces. Behind the main planes is a vertical rudder consisting of two trussed surfaces about 5½ feet long and one foot wide. Three levers are used for controlling the auxiliary surfaces and warping the main surfaces. The Wright motor is of their own make and is 4 cylinder water cooled. It develops about 25 H. P. at 1,400 R. P. M. There are two wooden propellers 8½ feet in diameter which run at about 400 R. P. M. The machine is supported on two runners, and weighs about 800 lb. A monorail is used in starting. The Wright machine attained a speed of between 40 and 45 miles per hour.

During the past 6 months the English monoplane "Valkyrie" has attracted worldwide attention. It will be remembered that when the Wright machine first appeared in France it was accused of flying tail foremost. Compared with the French machines the point seems to be fairly well taken. Further emphasis is added from the fact that the Wright Bros. have in some of their later machines been putting their horizontal rudder behind the main planes. The Valkyrie machine is a monoplane with a slight dihedral angle. The main supporting surface is 34 by 6 feet. In addition it has an auxiliary stationary plane in front. This auxiliary plane is 14 by 3 feet. It has 2 ailerons attached to the rear edge of the main planes

at their outer extremity. Their area each is 5 by 2 feet. There are two vertical rudders in the rear set eight feet apart. These rudders are 5 feet by 18 inches. The auxiliary front plane is 12 feet in front of the main plane, measured in the clear. Slightly to the rear and below this leading plane is placed the horizontal rudder which is eight feet by 26 inches. The unique feature of this machine is the stationary front plane. The vertical rudders in the rear are controlled by the feet of the operator. The single steering rudder controls the ailerons as well as the front rudder thus leaving one hand free. The machine is provided with wheels and skids. The weight of the complete machine is 520 lbs. The total area of the supporting surfaces is 232 square feet. The auxiliary plane in front has a greater angle of incidence than the main planes so that it has considerable supporting power. The machine is noted for exceptional fore and aft stability. About 30 H. P. in engine capacity is used. Great simplicity of design and construction characterize the whole machine as is well shown in the blue prints for which the speaker is indebted to Mr. Wm. Stout of Jack Knife fame. It will be noted also that in this machine the operator sits in front of the engine and has an unobstructed view, something not always accomplished in previous monoplanes.

In the operation of the Wright machine the so-called "rag indicator" is used and apparently nothing better has so far been found. This consists of a strip of tape or cloth such as might be torn from the side of a pocket handkerchief hung from the front rudder. One might reasonably expect a more expensive instrument for keeping track of the balance, but there is none. The rag answers the purpose. If it points up the operator knows he is going down, if it points down he knows he is going up. If it flutters out straight behind he knows all is well, and she is keeping an even keel. If it points to the one side or the other he knows he is skidding and the wing tips or ailerons must be brought into play to bring the machine back to a balance. The speaker has a "not-patented" improvement described in the 1911 Feb. "Aeronautics." It consists of an arrow with 4 vanes. The arrow is attached to the front rudder by a universal joint and is surrounded by a ring which serves as an index to tell how far the arrow is away from normal.

There is no part of the dynamic flying machine that requires more thorough study than the propeller. In his splendid article before the Am. Soc. of Mech. Engineers in Dec., 1908, Maj. Geo. O. Squier says: "The fundamental principles of

propellers are the same for air as for water. In both elements, the thrust is directly proportional to the mass of fluid set in motion per second. A great variety of types of propellers have been devised, but, thus far only the screw-propeller has proved to be of practical value in air. The theory of the screw propeller in air is substantially the same as for the deeply submerged screw-propeller in water."

This statement would appear to dismiss the subject as one of comparative simplicity. However if one of you should try to get a thrust of 1000 lbs. in water from a single propeller and then try to get the same result in air you would find that while the former was a matter of every day occurrence the latter was a bird of another color and that though some very bright minds have spent considerable gray matter on the problem, to date no one has succeeded.

Prof. Pickering of Harvard University in 1895 experimented with fans 18″ to 12′ in diameter using from .001 to 4.3 H. P. With his 6′ fan he obtained a lift of 254 lb. per H. P. but he lifted only ⅓ of a lb. and used .0013 H. P. In 1902 with a 20 H. P. motor and a 20′ fan he obtained a steady lift of 430 lb. or 21.5 lb. per H. P. Prof. Pickering states his conclusions as follows: "The lift (thrust) is a function of the work and the diameter, and the three quantities should all be given in order to make the observation of any value." The Wrights and Curtiss obtain thrusts of 6 to 8 lb. per H. P. on their propellers with diameters of 6 to 8½ feet. The Wrights use two propellers 8½ ft. in diameter running 400 R. P. M. Each propeller absorbs 14 H. P. Wilbur Wright claims 70 to 76% efficiency, but, as he has not defined the term efficiency as applied to air propellers his meaning is not entirely clear. These results are far inferior to Prof. Pickering's 21½ lb. per H. P. but of course a diameter of 20′ or more on an aeroplane propeller might not be usable. It is obvious that as the diameter increases, the efficiency increases, but if the propeller is to be of commercial size and usable in a flying machine, it must be strong enough to hold its pitch constant and transmit its thrust to the shaft as well as absorb the power transmitted to it. So then as the diameter increases, the weight increases, and the gain in efficiency is more or less offset by the added weight together with the unwieldiness of a large diameter.

It was considerations of this kind that led the speaker some 2 years ago to build a folding propeller of 25 feet diameter, but while the efficiency was improved the contrivance was unmanagable. (Vide, Aeronautics Feb., 1909).

The mystery of the Wright propeller seems to have been solved by an engineer, Capt. Eberhardt of the Royal Prussian Aerial Battalion of Berlin. You will find detailed drawings of these interesting propellers in the Nov. 1909 "Aeronautics." Capt. Eberhardt has worked out a formula for the thrust of the Wright propeller as follows:

$$N_1 = \frac{S\ s\ n}{75 \times 60}$$

where N_1 = work absorbed.
S = thrust, in kilos.
n = R. P. M.
s = pitch.

As the work absorbed is 14 H. P. per propeller we can substitute in the equation as follows:

$$14 = \frac{S \times 3 \times 400}{75 \times 60}$$

$$S = 52\tfrac{1}{2} \text{ Kilos.}$$

The head resistance of the Wright machine amounts to 100 Kilograms at 15 to 16 meters per second. If we denote the useful work by Ne, then the efficiency becomes

$$E = \frac{Ne}{N_1} = \frac{S\ c}{76.2\ N_1}$$

c, being the aeroplane speed.

Substituting in this formula we have,

$$E = \frac{52.5 \times 16}{76.2 \times 14} = 79\%$$

This probably explains what Wilbur Wright means by propeller efficiency. It is easy to see, however, that when one attempts to get at the efficiency of a propeller by measuring the thrust and horse power when there is no motion parallel to axis of revolution that his definition is not the only one needed by the student or designing engineer, to say the least.

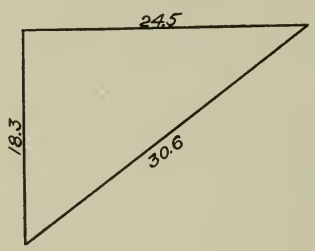
Mr. John Squires, Chief Mechanical Engineer of the E. R. Thomas Motor Car Co. defines propeller efficiency as the ratio between the work done in moving air to the power absorbed by the propeller. This definition also lacks many of the elements necessary to make it satisfactory. When a designer comes up to the question of actual blade design for his propeller—he is really facing the biggest problem of an engineering nature connected with the dynamic flyer. In so stating I am not unmindful of the great problem of automatic balance, which, however, at present is a problem requiring inventive genius as well as engineering skill.

Before presenting to you the Squires equations and the methods used in deriving them, I desire to present some observations relative to the Wright claim of 75% efficiency and Capt. Eberhardt's equations, his computed head resistance, horse power used, etc.

Mr. Orville Wright in their light roadster has a 30.6 H. P. motor. The total weight including himself was 800 lbs. With it he climbed 757 feet in one minute. The output of useful work in climbing was therefore,

$$\frac{800 \times 757}{33000} = 18.3 \text{ H. P.}$$

or an efficiency of 60% without giving credit for the head resistance of the air. Mr. Wright states that in horizontal flight they use about 15 H. P. and this climbing data would seem to partially substantiate his claim. It also shows the reserve power of the Wright flyer. If we plot the total horse power of the engine as hypothenuse and the vertical component as one side of a right angle, we see that there is still 24½ H. P. available for the horizontal component.



Mr. John Squires, so far as I know, has gone into the propeller question on the experimental side about as thoroughly as any one and his formulae are interesting, because he has proved them in the laboratory. Mr. Squires defines propeller efficiency as the ratio of work done in setting air in motion to the work delivered to the propeller through the shaft.

The first equation is the old familiar $W = \frac{1}{2}M V^2$, this becomes $W = w V^2/2 g$, where w is the weight of air moved, but w is made up of units of weight w_1 (in this case we take 1 cubic foot of air as the unit). Then if there are a total of C units, we have $W = C w_1 V^2/2 g$. Now as C depends on Area swept over, the Pitch, and the number of Revolutions, if we denote these quantities by A, P and R, our equation becomes $W = (APR) w_1 V^2/2 g)$.

As V equals the velocity at which the mass travels, we

can factor farther by substituting $(P\ R)^2$ for V^2. Then our equation becomes by substitution and transposition

$$A\ P^3\ R^3\ w_1 / 2\ g\ W = 1.$$

This is the Squires equation for propellers and the equation which has been tried out by experiment. In it you see the four variants involved in propeller design. Viz. A, P, R and W.

The thrust of a propeller comes directly from the formula for wind pressure. P = Thrust $= K\ V^2\ S$.

In these two formulas $V^2 = (P\ R)^2$ and $A = S$.

Remembering all the time that the thrust varies as V^2 we can draw the following interesting conclusions from the Squires formula. (See Squires paper "Aeranautics" June, 1909.)

"(1) Doubling the speed without altering the pitch or area, alters (increases) the power with the cube of the speed, and alters (decreases) the thrust per unit of power inversely with the speed.

(2) Doubling the speed and halving the area without altering the pitch, alters the power with both the speed and the area, increasing it with the cube of the speed and decreasing it directly with the area, which is practically equal to altering (increasing) it with the square of the speed, and alters (decreases) the thrust per unit of power inversely with the speed.

(3) Doubling the speed and halving the pitch without changing the area alters neither the power nor the thrust per unit of power.

(4) Doubling the area without altering the speed or the pitch alters (increases) the power directly with the area, and does not alter the thrust per unit of power.

(5) Doubling the area and halving the speed without altering the pitch alters the power with both the area and the speed, increasing it directly with the area, and decreasing it with the cube of the speed, which is practically equal to altering (decreasing) it inversely with the square of the speed, and alters (increases) the thrust per unit of power inversely with the speed.

(6) Doubling the area and halving the pitch without altering the speed, alters the power with both the area and the pitch, increasing it with the area and decreasing it with the cube of the pitch, which is practically equal to altering (decreasing) it inversely with the square of the speed, and alters

(increases) the thrust per unit of power inversely with the pitch.

(7) Doubling the pitch without altering the speed or area alters (increases) the power with the cube of the pitch, and alters (decreases) the thrust per unit of power inversely with the pitch.

(8) Doubling the pitch and halving the speed without altering the area does not alter the power or thrust per unit of power.

(9) Doubling the pitch and halving the area without altering the speed alters the power with both the pitch and the area, increasing it with the cube of the pitch and decreasing it directly with the area, which is practically equal to altering (increasing) it with the square of the pitch, and alters (decreases) the thrust per unit of power inversely with the pitch.

(10) Doubling the speed and doubling the area without altering the pitch alters (increases) the power with the cube of the speed, and also directly with the area, which is practically equal to altering (increasing) it with the fourth power of the speed, and alters (decreases) the thrust per unit of power inversely with the speed.

(11) Doubling the speed and doubling the area, and halving the pitch, alters (increases) the power with the cube of the speed, and also directly with the area, but also decreases it with the cube of the pitch, which is practically equal to altering it (increasing) directly with the area, and does not alter the thrust per unit of power.

(12) Doubling the speed and doubling the pitch without altering the area alters (increases) the power with the cube of the speed, and also with the cube of the pitch, which is practically equal to increasing it with the sixth power of the speed and alters (decreases) the thrust per unit of power inversely with the square of the speed.

(13) Doubling the speed and doubling the pitch, and halving the area, alters (increases) the power with the cube of the speed, and with the cube of the pitch, but also alters (decreases) it inversely with area, which is practically equal to increasing it with the fifth power of the speed, and alters (decreases) the thrust per unit of power inversely with the square of the speed.

(14) Doubling the area and doubling the pitch without altering the speed alters (increases) the power directly with the area and also with the cube of the pitch, which is practi-

cally equal to increasing it with the fourth power of the pitch, and alters (decreases) the thrust per unit of horse power inversely with the pitch.

(15) Doubling the area and doubling the pitch, and halving the speed, alters (increases) the power directly with the area, and also with the cube of the pitch, but also alters (decreases) it inversely with the cube of the speed, which is practically equal to increasing it directly with the area, and does not alter the thrust per unit of power.

(16) Doubling the speed and doubling the area, and doubling the pitch, alters (increases) the power with the cube of the speed, and also directly with the area, and also with the cube of the pitch, which is practically equal to increasing it with the seventh power of either the speed or the pitch, and alters (decreases) the thrust per unit of power inversely with the square of the speed.''

It must be borne in mind that effective swept-over area is meant.

It is entirely possible to design a propeller which will exert its work over the entire area swept by the blades. Consequently, perfect efficiency is the effect of air blowing against this area with a velocity equal to the pitch speed of the propeller minus head resistance, and surface friction of hub and blades.

The Squires formula points out facts concerning the equal efficiency of high and low speed propellers for doing the same work so plainly that they are scarcely believable, and are surely of supreme importance in attaining correct cross section, correct outline shape, and correct number of blades which are the goal of the designing engineer.

It is true that there is no standard cross section nor outline of blade that is correct under more than moderately diversified working conditions, and although it is possible to get full swept area propulsive effect, correct blades and proper number of blades are requisite to do so.

A study of the Squires formula will show that two propellers may have the same efficiency and one have eight times the thrust of the other.

Now these formulae and deductions have not had to do with propellers in flight, and it can be shown that though a propeller has high thrust against a fixed point, it does not follow that the machine to which it is attached will travel faster through the air than one with a lower thrust per horsepower. Time has not permitted my going into this latter

phase of the matter, and, besides, I am not aware of any experimental data on the subject.

By way of a practical application of these formulae suppose we have a 20 H. P. engine at 1,200 R. P. M. with room for an eight foot propeller, all of which is within practical limits, and we want to compute the pitch. We have by putting in the numerical values,

$$\frac{50 \times P^3 \times 8000 \times .073}{64.32 \times 11000} = 1$$

which solved gives $P = 2.893$.

To compute the thrust we have to substitute in the other formula and have

$T = A\ v^2\ .00139 = 50 \times (2.893 \times 20)^2 \times .00139 = 232.67$ lb. or 11.6 lb. per H. P.

A great deal might be said about the errors creeping into calculations using the wind pressure coefficient without due regard to density and temperature differences, and the velocity with which the air is being handled, as well as the speed of the machine to which the propeller is attached. I have not expected to cover propeller design, but only to draw attention to its importance in aviation.

As students of engineering, especially those of you who in June, 1912, or later, will be candidates for degrees and expected to present original theses, aviation offers a field both interesting and rich in opportunities. That many of you are interested goes without saying and that not a few will make a life work of it I firmly believe.

There are certain sources of information which once acquainted with, open up to you the main avenues of approach to this most interesting subject. I will enumerate a few, which, if followed up will give you about all there is available, i. e., if you keep an eye open for references as you read and study.

First. In the back of Maj. Squier's paper, you will find a bibliography of Aeronautical Works, which is the most complete in existence. It contains the titles, etc. to about 350 books and treatises on the subject. This paper was read before the A. S. M. E. Dec., '08, at New York.

Second. The files of "Aeronautics" are the greatest single source for events of the past four years.

Third. The English paper "Flight" is also good.

However, the Squier paper itself is exceptionally fine, and if interested you should get it. The A. S. M. E. sells it at 80 cents.

Some of you may want to get a lot of data on dynamic flyers in the way of weights, dimensions, types, etc. There have been to date two great Aviation meets: Rheims, France, in Sept., '09, and Belmont during the past autumn. Tables giving data on all the American and foreign machines entered in both meets can be found in "Aeronautics" for Oct. '09 and Dec. '10. A very condensed historical table is given by Chanute in "Aeronautics" for Jan., '09.

At this point I want to inject a few records I have gathered and which show the progress of the Aviation world to date.

They are as follows:

(A) Duration.
Farnham 8 hours and 12 minutes at Buc., France, Dec. 18, 1910.

(B) Distance.
Tabuteau, 362.88 miles, Dec. 30, '10.

(C) Altitude.
Legagneau, 10,430′, Pau, France, Dec. 9, '10.

(D) Two Man Flight, 132 miles.

(E) Ladies Flight, 103 miles, 2 hours 35 minutes.

(F) No. of People, 12, Louis Bregnet, Dovai, France, March 23rd, 1911. (Distance, two miles).

Considering the time that has passed since the Wrights first got off the ground in their power driven machines, isn't it enough to make the blood in a young man's veins tingle?

I want to close my address to you with a few observations about soaring flight or flying without either gas bag or motor. It is to be remembered that the first human flights were made in this way. In the 11th Century Oliver Malmesbury made a glide of 370 feet. In 1867 Le Bris soared 600 feet and used warping wings. But in 1892 Lilienthal made over 3,000 glides of about 600 feet. In 1894 Daniel Moloney glided ¾ of a mile to a previously determined spot, starting from a hot air balloon at an elevation of 4,000 feet. The Brothers Wright made hundreds of glides before they put a motor on their glider.

You all know how, when a subject is being attacked, a little success in one direction often leads to complete abandonment of very promising fields in nearly all other directions. So in aviation—the success of the power driven aeroplane has caused the temporary neglect of the ornithopter, the helicopter and also of soaring flight.

I am fully aware that any engineer is somewhat out of his sphere when he turns prophet. However I will confine myself largely to the sayings of Langly and Chanute, who have passed

to that country from whose bourne no traveler returns, and to whom the civilized world will ever be indebted as the two great pioneers of aviation. These men were among the foremost scientists and engineers of our time, Chanute gone but a few months and Langley but a few years.

Chanute's last contribution to aviation, a subject enriched by him more than by any one else, was entitled "Soaring Flight." "How to perform it." (Vide Mr. O. Chanute's article Aeronautics April, 1909). I can't say that I believe that very soon our boys and girls will flit through the air around the home or neighborhood, as the young lambs now gambol over the green pastures, and yet no one is in position to prove the negative. It's a subject I commend to you most seriously, because a glider is easy to make and there is a fine lot of data to be gathered. The proportions of the subject are well within the time and energy usually put into a good thesis.

SOARING FLIGHT.

"There is a wonderful performance daily exhibited in Southern climes and occasionally seen in Northerly latitudes in summer, which has never been thoroughly explained. It is the soaring or sailing flight of certain varieties of large birds who transport themselves on rigid unflapping wings in any desired direction; who, in winds of 6 to 20 miles per hour, circle, rise, advance, return and remain aloft for hours without a beat of wing, save for getting under way or convenience in various maneuvers.

This feat is so much opposed to our general ideas of physics that those who have not seen it sometimes deny its actuality, and those who have only occasionally witnessed it subsequently doubt the evidence of their own eyes. Others, who have seen the exceptional performances, speculate on various explanations, but the majority give it up as a sort of "negative gravity."

A still greater mystery was propounded by the few observers who asserted that they had seen buzzards soaring in a dead calm, maintaining their elevation and their speed. Among these observers was Mr. E. C. Huffaker, at one time assistant experimenter for Professor Langley. Mr. Chanute believed and said then that he must in some way have been mistaken, yet, to satisfy himself, he paid several visits to Mr. Huffaker, in Eastern Tennessee and took along his anemometer. He saw quite a number of buzzards sailing at a height of 75 to 100 feet in breezes measuring 5 or 6 miles an hour at the sur-

face of the ground, and once he saw one buzzard soaring apparently in a dead calm.

Mr. Chanute was fairly baffled. The bird was not simply gliding, utilizing gravity or acquired momentum, he was actually circling horizontally in defiance of physics and mathematics. It took two years, and a whole series of further observations to bring those two sciences into accord with the facts.

These observations disclosed several facts:

1st. That winds blowing five to seventeen miles per hour frequently had rising trends of 10 degrees to 15 degrees, and that upon occasions when there seemed to be absolutely no wind, there was often nevertheless a local rising of the air estimated at a rate of four to eight miles or more per hour. This was ascertained by watching thistledown and rising fogs alongside of trees or hills of known height. Everyone will readily realize that when walking at the rate of four to eight miles an hour in a dead calm the "relative wind" is quite inappreciable to the senses and that such a rising air would not be noticed.

2nd. That the buzzard, sailing in an apparently dead horizontal calm, progressed at speeds of fifteen to eighteen miles per hour, as measured by his shadow on the ground. It was thought that the air was then possibly rising 8.8 feet per second, or six miles per hour.

3rd. That when soaring in very light winds the angle of incidence of the buzzards was negative to the horizon—i. e., that when seen coming toward the eye, the afternoon light shone on the back instead of on the breast, as would have been the case had the angle been inclined above the horizon.

4th. That the sailing performance only occurred after the bird had acquired an initial velocity of at least fifteen or eighteen miles per hour, either by industrious flapping or by descending from a perch.

5th. That the whole resistance of a stuffed buzzard, at a negative angle of 3 degrees in a current of air of 15.52 miles per hour, was 0.27 pounds. This test was made by Professor A. F. Zahm in the "wind tunnel" of the Catholic University at Washington, D. C., who, moreover, stated that the resistance of a live bird might be less, as the dried plumage could not be made to lie smooth.

This particular buzzard weighed in life 4.25 pounds, the area of his wings and body was 4.57 square feet, the maximum cross section of his body was 0.110 square feet, and that of

his wing edges when fully extended was 0.244 square feet.

With these data, it became surprisingly easy to compute the performance with the coefficients of Lilienthal for various angles of incidence and to demonstrate how this buzzard could soar horizontally in a dead horizontal calm, provided it was not a vertical calm and that the air was rising at the rate of four or six miles per hour, the lowest observed, and quite inappreciable without actual measuring.

Mr. Chanute determined, however, to withhold publications until the feat of soaring flight had been performed by man, partly because he believed that, to ensure safety, it would be necessary that the machine should be equipped with a motor in order to supplement any deficiency in wind force.

The feat would have been attempted in 1902 by Wright Brothers if the local circumstances had been more favorable. They were experimenting on "Kill Devil Hill," near Kitty Hawk, N. C. This sand hill, about 100 feet high, is bordered by a smooth beach on the side whence come the sea breezes, but has marshy ground at the back. Wright Brothers were apprehensive that if they rose on the ascending current of air at the front and began to circle like the birds, they might be carried by the descending current past the back of the hill and land in the marsh. Their gliding machine offered no greater head resistance in proportion than the buzzard, and their gliding angles of descent are practically as favorable, but the birds performed higher up in the air than they.

Professor Langley said in concluding his paper upon "The Internal Work of the Wind:"

"The final application of these principles to the art of aerodromics seems, then, to be, that while it is not likely that the perfected aerodrome will ever be able to dispense altogether with the ability to rely at intervals on some internal source of power, it will not be indispensable that this aerodrome of the future shall, in order to go any distance,—even to circumnavigate the globe without alighting—need to carry a weight of fuel which would enable it to perform this journey under conditions analogous to those of a steamship, but that the fuel and weight need only be such as to enable it to take care of itself in exceptional moments of calm."

Now that the dynamic flying machines have been evolved and are being brought under control, it seems to be worth while to make these computations and the succeeding explanations known, so that some bold man will attempt the feat of soaring like a bird. The theory underlying the performance in a rising wind is not new, it has been suggested by Penaud

and others, but it has attracted little attention, because the exact data and the maneuvers required were not known and the feat had not yet been performed by a man. The puzzle has always been to account for the observed act in very light winds, and it is hoped that by the present selection of the most difficult case to explain—i. e., the soaring in a dead horizontal calm—somebody will attempt the exploit. Vide Addenda.

The following are deemed to be the requisites and maneuvers to master the secrets of soaring flight:

1st. Develop a dynamic flying machine weighing about one pound per square foot of area, with stable equilibrium and under perfect control, capable of gliding by gravity at angles of one in ten (5¾°) in still air.

2nd. Select locations where soaring birds abound and occasions where rising trends of gentle winds are frequent and to be relied on.

3rd. Obtain an initial velocity of at least 25 feet per second before attempting to soar.

4th. So locate the center of gravity that the apparatus shall assume a negative angle, fore and aft, of about 3°. Calculations show, however, that sufficient propelling force may still exist at 0°, but disappears entirely at +4°.

5th. Circle like the bird. Simultaneously with the steering, incline the apparatus to the side toward which it is desired to turn, so that the centrifugal force shall be balanced by the centripetal force. The amount of the required inclination depends upon the speed and on the radius of the circle swept over.

6th. Rise spirally like the bird. Steer with the horizontal rudder, so as to descend slightly when going with the wind and to ascend when going against the wind. The bird circles over one spot because the rising treads of wind are generally confined to small areas or local chimneys, as pointed out by Sir H. Maxim and others.

7th. Once altitude is gained, progress may be made in any direction by gliding downward by gravity.

The bird's flying apparatus and skill are as yet infinitely superior to those of man, but there are indications that within a few years the latter may evolve more accurately proportioned apparatus and obtain absolute control over it.''

If the speaker has succeeded in arousing additional interest in the general subject, he will have served his purpose; if

some of you find out first hand some new facts about propellers, or better still, if you should contribute something to the subject of soaring flight and give your results to the public—he would feel himself many times repaid for his feeble efforts at this time.

Take the most difficult case of the buzzard, viz. A horizontal calm and a vertical current of 6 miles per hour (8.8 feet per second), and assume a previously acquired initial speed of 17 miles per hour (24.93 feet per second). Then we have

$$6/17 = .353 = \text{tan. } 19° \ 26'.$$

But the buzzard flew at angle of 3° so that his relative angle was reduced to 16° 26′. The relative speed was

$$\sqrt{17^2 + 6^2} = 18.03 \text{ miles per hour.}$$

Using the Langley coefficient we have as the air pressure

$$18.03 \times .00327 = 1.063 \text{ lb. per square foot.}$$

Applying the Lilianthal coefficient for 16° 26′ we have

Normal $4.57 \times 1.063 \times .912 = 4.42$.

Tangential $4.57 \times 1.063 \times .074 = -.359$, a propelling force since the angle is negative. Zahm's .27 resistance makes

$$.27 \times \frac{17^2}{15.52^2} = .324$$

therefore the work is

$$.324 \times 24.93 = 8.07 \text{ f. p. s.}$$

The energy of rising air at 4 miles per hour does not provide sufficient energy it giving only 2.1 f. p. s. At 7 miles per hour we have, (using Langly's coefficients)

$4.57 \times 16 \times 10.26 = 7.5$ f. p. s. close enough when we consider that the Langly coefficient was deduced from planes, while the buzzards wings are curves.

Cos. Mag. Apr., '11, says: "O. Wright descending one day discovered at 1000′ that he had stopped coming down. When he reached the earth he said: 'I thought I would never get down. If I had shut off my power, I feel certain I could have soared upward without the least power to lift me!' "

The author has drawn freely from the following papers to which due acknowledgement is made:—

"The Present Status of Military Aeronautics," Maj. Geo. O. Squier, A. S. M. E., Jan., 1908.

"Soaring Flight," O Chanute, "Aeronautics," April, '09.

"Propeller Mathematics for the Kindergarden Class," John Squires, "Aeronautics," June and Aug., 1909.

PERMANENT HARBOR WORK AT SAN FRANCISCO

Louis P. Zimmerman, E. E. '08

San Francisco, California, the metropolis of the Pacific coast, is among the first of the seaport cities of the United States in harbor improvement and the building of permanent docks and wharves. In April, 1906, practically the entire city was destroyed by fire and earthquake. The immediate effect of this calamity on the industries of San Francisco was an almost total paralysis of all activity. There were very few plants or buildings that were not either wholly or partially destroyed. During the last four years, however, reconstruction has been carried on vigorously, until to-day the physical equipment of the business sections is equivalent to and in some instances, superior to what it was before the earthquake.

In this fire, the people of San Francico had one great fact pointed out to them and that was the corporative insignificance and fraility of the best works of man. It also established the fact that permanent, fireproof construction is what must be sought for in the making of our great cities.

Fortunately, very little of the waterfront and docks on San Francisco bay was damaged by fire of April 19, 1906. For many years the waterfront improvement work has been under the control of the State Board of Harbor Commissioners. Their great work in building up the ferry system between San Francisco and the suburb cities Oakland, Berkey, Alemeda and Sausolito across the bay, is commented on by every visitor to the Golden Gate City. In their aim to gather in the commerce of the Orient, th State Board of Harbor Commissioners has paid particular attention to the construction of piers, and sea walls on the many miles of waterfront available for shipping.

In 1910 the first two concrete piers on the Pacific coast were completed. On both sides of the ferry building which is the center of the waterfront, permanent concrete sea walls are being placed back of these piers. The water front line of San Francisco, under the jurisdiction of the State Board of Harbor Commissioners, is approximately 8 miles in length. On June 30th, 1910, there were in existence along this line, 11,700.5 feet of completed seawall and 23 seawall lots. By the construction of a new seawall and the reclamation of the land between it and the previously existing city front, the property area is gradually increased.

During the last two years the construction of a new seawall has been prosecuted as rapidly as the conditions would permit. Three sections are now under construction. The design being used on the last three is a departure from that previously used. The original wall construction consisted of a broken stone core, topped with rubble masonry above the water line. This has been found to be somewhat unsatisfactory, as it allowed the tide to flow through and carry away the fill behind the wall. The new seawall construction consists of a concrete wall, supported on piles, and having a rock fill below and on both sides of it. The base of the concrete is 30 feet below city datum.

Section 8 is designed to support buildings, additional ferry facilities and to afford a base for additional slips, and for this reason no bulkhead wharf is placed upon it. A cross section of the wall shows the top at city elevation, zero, with a width of 3 feet. The back of the wall is perpendicular and extends to a depth of 30 feet, where the base measures 30 feet. Four rows of piles spaced 2½ feet centers support the base. Back of the walls a rock fill with a natural slope covers the lower 8 feet of the wall. On the outside of the wall a rock embankment with a 30 degree slope is brought up to the base of the wall and 22 feet in front of it. From this point up to mean low water elevation, a natural slope is given the rock fill, which stops at this point.

Section 9 and 10 are designed to form the base for piers and have bulkhead wharves upon them. All recent bulkhead construction has been entirely of concrete and steel. These concrete bulkhead wharves built in connection with a solid concrete wall have two decided advantages over the wooden wharves found on the other sections of the waterfront. They are absolutely fireproof and afford no opportunity for vermin to exist. The bulkhead wharves are of concrete built on 20 inch I-beams supported on wooden piles coated with a concrete casing extending below the rock fill, to protect them from the teredo. 42 foot fender piles backed with car springs and 4 by 16 inch ribbing, are placed just outside of the waterfront line.

In connection with the work on the wharf with construction, and relative tests of wood and conrete piles, Mr. Barker, assistant state engineer, has completed some very extensive tests on the value of the eucalyptus trees for piling. A great many claims have been put forward that certain varieties of eucalyptus trees would resists the attacks of the teredo and the limnoria. This claim was

Section 8 of the concrete sea-wall, showing rock embankment on the sea side of the wall.

Driving the steel casings for concrete piles for pier 26. The steel casings are removed after the concrete base has set, leaving the wooden forms in place.

made for the blue gum variety, which is quite plentiful in California, and is available in suitable sizes for piling. The State Board of Harbor Commissioners decided to make a test of these trees and about 1,200 were purchased and put into structures where the teredo was known to be active. About 250 of these trees came from the city of Berkley, in Alemeda County, where they were planted in 1872 and were therefore 37 years old when cut; the balance came from the Parkside division of San Francisco and were from 24 to 28 years old. All were of the same variety, i. e. Eucalyptus globulus. These piles were driven in 1909, and, although they have not been in service long enough to determine their value fully, they have been found very little better than fir. A large number were used in the construction of one of the ferry slips at the foot of Market Street. It was thought that the wood being tough and strong, would resist the blows and wear of ferry boat service better than fir piling, but the result has been a disappointment. The eucalyptus does not stand the wear any better than fir, and does not afford enough rigidity for ferry slip construction on account of the rapid taper and the ease with which the piles are bent.

The eucalyptus tree is not a native of the United States but has been imported and planted here, and many claims have been advanced, as to its value, but reports from other countries indicate that they are not well founded.

H. Cullen, engineer for harbors and rivers, Brisbane Queensland, says:

"For fender piles our practice is to use swamp mahogany or cypress pine. These timbers both possess a resin obnoxious to the teredo and the limnoria, but the quality and quantity seem to vary for reasons not quite understood. However, apart from these variations, both timbers possess a certain resistance to attack, varying in length from three to 20 years. Many piles of these timbers are now in existence on the coast, that have been in place for 15 or 20 years, while I have known cases where the life was only three to four years. In New South Wales credit is given to a timber called turpentine for insect resisting properties, and it is largely used there. Our experience in Queesland with the same timbers has not borne out the claims made for it in New South Wales."

San Francisco is the first of the large seaports on the Pacific coast to take up and push the development of its wharves and waterfront to meet the demands now made upon it by shipping. The character of the carriers employed in coast transportation is entirely different from those of a few

Section 10 of the concrete seawall being constructed along the water front of San Francisco Bay. All piling and old wharves are being removed and the area back of the seawall filled in to form seawall lots.

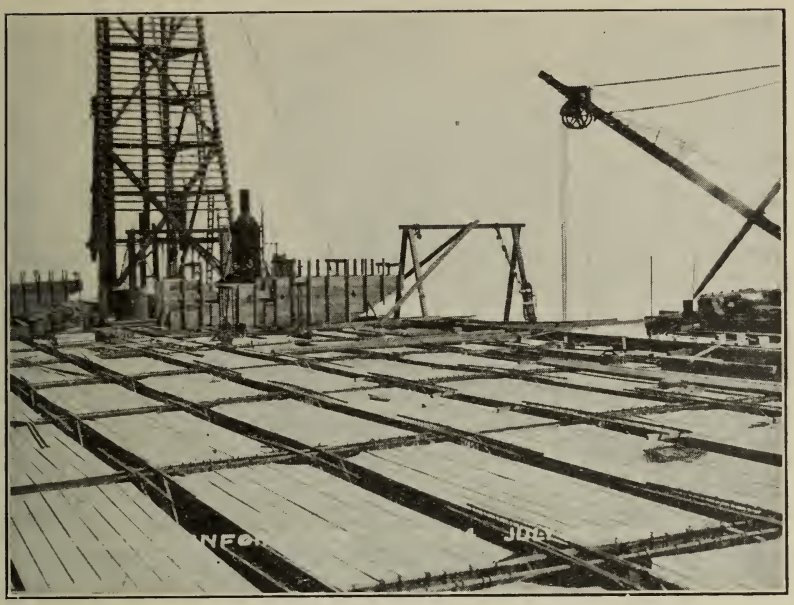
years ago, when much of the shipping consisted of sailing vessels of comparatively small tonnage.

These did not have any sailing schedules and discharged their cargo in a leisurely way. This did not require piers or a waterfront that could accommodate a large quantity of freight as it could be hauled away almost as fast as it was received. Now the carriers are principally large steam vessels carrying from 6,000 to 12,000 tons of cargo, and operating on a fixed schedule and are so expensive to operate that their lay-time must be the least possible. Every means of hastening the discharge and taking on of cargo is employed. The result is that an enormous amount of freight is piled upon the piers and wharves and they very soon become congested.

In the rebuilding of the wharves and water front these conditions are being met. All piers are being equipped with spur tracks from the belt line railroad, and so connected with the main and spur lines of the various railroads, that cars can be distributed without delay. A 100 foot roadway is being completed along the waterfront for use of teams that handle goods and material directly to and from the wharves and warehouses. With the completion of a short stretch now under construction, this roadway will be continuous between China basin, the big freight wharves and the Ferry building at the foot of Market Street.

The average width of the piers in San Francisco harbor is at present about 100 feet. The largest are 140 feet in width and a few old ones are only 80 feet. The latter are what is left of the old construction when large steamers were comparatively scarce in San Francisco trade. The piers now being designed for section 9 and 10 of the new seawall, are 209 feet in width, with depressed railroad car tracks along the center of each. This will allow sheds 80 feet in width if two tracks are provided, and 86 feet if one track if provided, on each side of the track, and will leave 10 feet, between the edge of the pier and the shed.

This will afford facilities for the handling of general cargoes which must be sorted before going into the cars, and cargoes can be placed directly in cars by the ships' tackle with overhead cranes for handling heavy pieces of cargo. Several of the piers will be provided with outside trackage, so that cargoes can be handled directly into the ship's holds. The space between the piers along the seawall is being increased to meet the demands of the larger ships, and in the new piers, the width of the slips will be 220 feet.



Floor beam reinforcement for Pier 54.

Pier 36 recently completed, is provided with a ferry slip and apron for handling freight cars. The outer end of pier 36 was built of wood to better absorb the shock of incoming car floats and ferry boats. On one side of the pier is a shed, a railroad track; between the shed and the edge of the pier the outer side is open and provided with trackage.

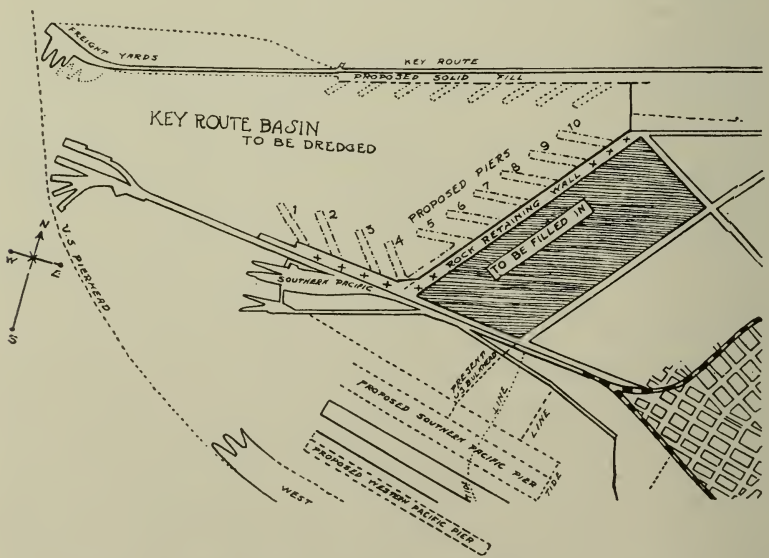
Pier 54, just completed, is built entirely on reinforced concrete except the shed, which is of wood. It has a depressed track on one side. In floor space it is the largest pier on the San Francisco waterfront, measuring 780 feet in length and 140 feet in width. Pier 54 is located at the farther end of the waterfront roadway, being adjacent to the trackage systems of the San Francisco and San Joaquin Railroad Co.

Work on a great inland harbor, which promises to be one of the greatest municipal shipping projects in the United States, was started by the city of Oakland, California, on December 14th, when the board of public works of that city let the contract for the construction of the rock retaining wall along the new bulkhead line which is to serve as a quay in the the Key Route Basin, and will be the outer margin of 400 acres of land, which is to be filled in by the city. The amount of the initial contract was $47,540. The estimates of the city engineer call for an expenditure of $350,000. In addition to this amount the Key Route Company, is preparing to expend $500,000 as its share of the development of the harbor.

The Key Route Basin will be dredged to a minimum depth of 30 feet along the entire frontage of 7,000 feet which is to be the length of the proposed quay wall. The quay will be owned absolutely by the City of Oakland, and the structure will be built so that the frontage can be more than trebled, by the construction of piers, as fast as the room is needed. The back of the wall will be platted and streets cut through, giving easy access to the warehouse and business district. It is estimated that the value of the land thus reclaimed will be about $6,000,000.

The development of the basin as planned by the city is in strict accordance with the requirements laid down by the war department. The department has given the city permission to fill out to a point 2,000 feet west of the old bulkhead line, thus making possible the creation of the 400 acres of water front land. The city is required by the war department to start the work within one year and to have it completed within six years. Col. John Biddle, chief engineer of the department of California, in charge of river and harbor work, has given the plans his approval and it was on his recommendation that the city received permission to carry on the work.

The Southern Pacific Company, has its engineers at work on plans for the erection of a series of wharves, which will provide berthing facilities for a large number of vessels, and the Western Pacific Company has plans for the extension of its water front facilities. The improvements will mean much



Map of improvements started along the western water front of Oakland, Cal. across the bay from San Francisco.

to the City of Oakland and will give that city unsurpassed facilities for handling overland freight direct to the largest vessels plying the Pacific.

The action and work of San Francisco and Oakland in improviding and building permanent seawalls and fireproof concrete piers is being watched very closely by the other seaport towns on the Pacific coast. That the value of substantial improvements is being recognized and acted upon is apparent from the steps taken by Portland and Tacoma, in beginning the construction of public docks and wharves.

AN EXAMPLE OF INGENIOUS CURVE PLOTTING

Harley G. Overholt, C. E. '10

The set of curves herein described was originated and worked out by H. W. Youngberg, C. E. Armour 1908. With Mr. Youngberg's consent the writer has prepared this description and explanation of the graphical solution o fa complex equation.

The equation was derived from the formula for shear reinforcement in a concrete beam as given by Turneaure & Maurer,* viz.

$$a \quad fs = .8 \; v \; b \; r \qquad (1)$$

In beams, where the bending moment governs the design and unit-stresses of 750 pounds per square inch in the concrete and 13,500 pounds per square inch in the steel are to be reached simultaneously, the formula, solved for r, becomes

$$r = 6\,l\left(1 - \sqrt{1 - \frac{310\ a}{l\sqrt{w}}}\right) \qquad (2)$$

a = area of steel into the cosine of the angle which the steel makes with a 45° plane sloping upward towards the support.

l = length of span in feet.

w = uniform load in pounds per square foot.

r = distance in inches (adjoining the support) in the direction of the span for which a is sufficient to carry the shearing stresses.

The diagram consists of two parts. The first part gives the value of $\frac{310\ a}{l\sqrt{w}}$. The second part gives the value of r for the value of $\frac{310\ a}{l\sqrt{w}}$ found in the first part.

Figure 1 shows the construction and manner of using. Two origins OX and O′X′ are taken at a distance of log 310 apart. From O′X′ values of log $\sqrt{w}$ are plotted below. From OX as an origin values of log 1/l are plotted below to the same scale. From a vertical origin OY, values of log a are plotted to the right. Across the field are drawn some lines at 45° to serve as guides.

* See pages 223 and 225 in "Principles of Reinforced Concrete Construction"—1910 Edition.

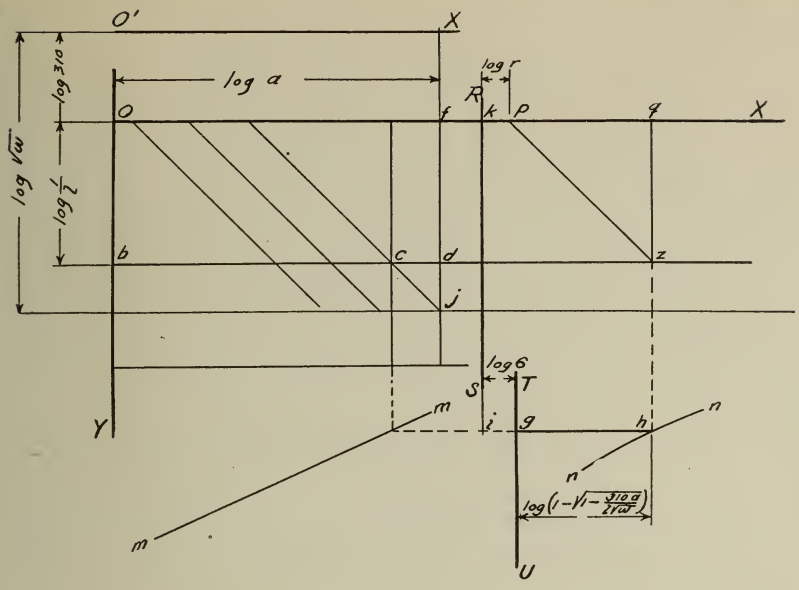


Figure 1

For given value of a and w, a point j at the intersection of the lines representing those values is determined. Proceeding at 45° from point j to the line representing a given value of l, a point c is determined. The horizontal distance b c represents the value of the term $\frac{310\ a}{l\sqrt{w}}$ to the same scale as a is plotted.

For $bc = bd - cd = bd - dj.$

$dj = ej - ed = ej - (ef + fd)$

$bc = bd - ej + ef + fd$

i. e. $bc = \log a - \log \sqrt{w} + \log 310 + \log 1/l$

$$= \frac{310\ a}{l\sqrt{w}}$$

From the point c drop to the sloping line m-m (drawn at any slope) thence to the right to the line TU. RS and TU are two vertical lines drawn at a distance of log 6 apart. Proceed beyond line TU a distance

$$gh = \log\left(1 - \sqrt{1 - \frac{310\ a}{l\sqrt{w}}}\right)$$

Thence up again to the line representing l, thence up at 45° to the line OX at the point p. At point p, read the value of r as determined from $\log r = k\ p.$

For $kp = kq - pq$

$kq = ig + gh$ and $pq = qz$

$kp = ig + gh - qz$

$$kp = \log 6 + \log\left(1 - \sqrt{1 - \frac{310\ a}{l\sqrt{w}}}\right) - \log\frac{1}{l}$$

$$= \log 6\,l\left(1 - \sqrt{1 - \frac{310\ a}{l\sqrt{w}}}\right)$$

$$= \log r \quad \text{by Equation.} \qquad (2)$$

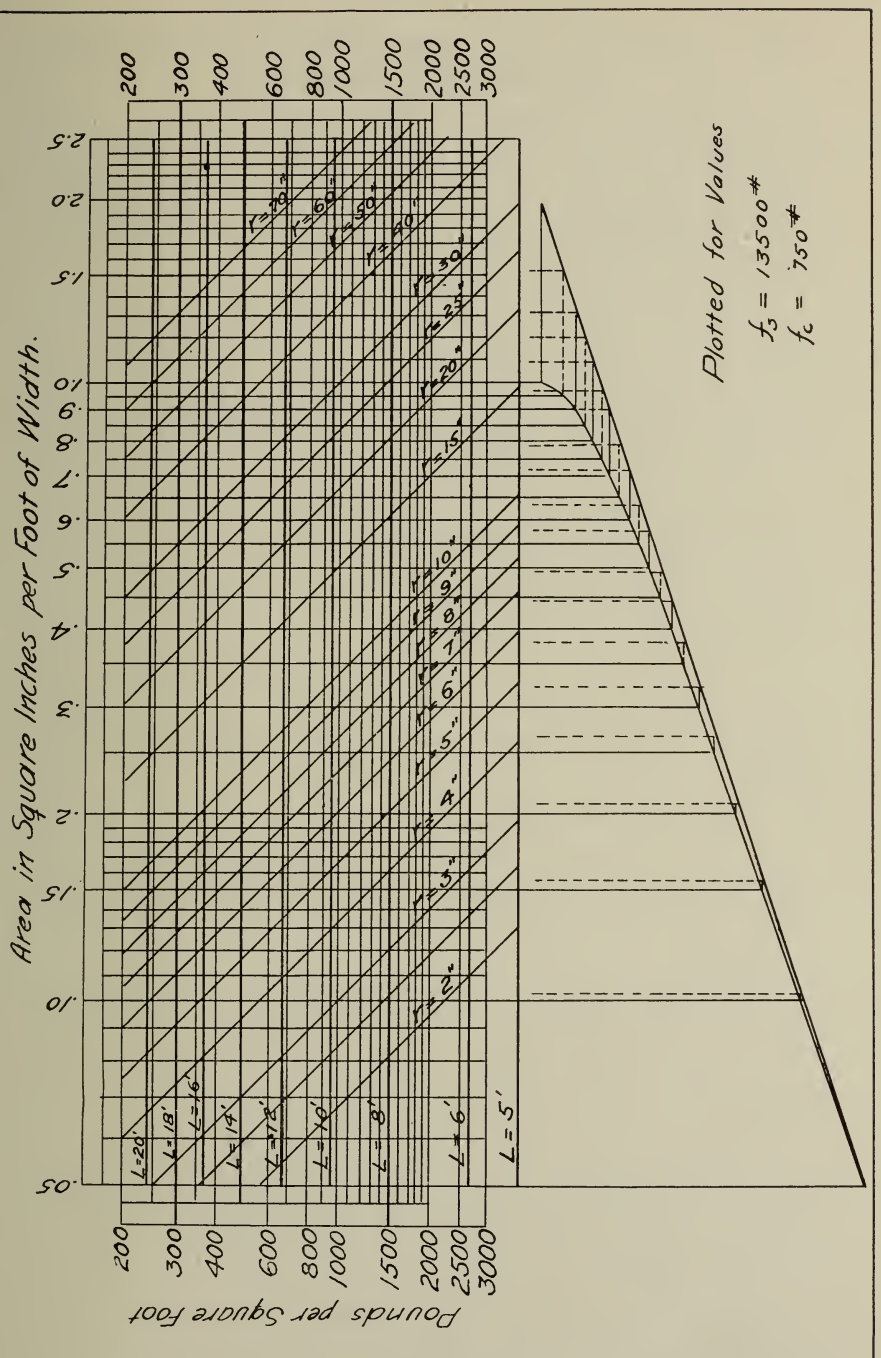
In drawing the curve n-n which gives the point h, values of l and w were taken so that $l\sqrt{w} = 310$. Then

$$\log\left(1 - \sqrt{1 - \frac{310\ a}{l\sqrt{w}}}\right) \text{ becomes } \log\left(1 - \sqrt{1 - a}\right)$$

and it was only necessary to move down the lines representing values of a to line m-m, thence beyond line TU by the distance

$$\log\left(1 - \sqrt{1 - a}\right)$$

To aid in reading values of r, the 45° lines were marked with the value of r at which they intersected the line OX. Then the second part of the diagram was shifted over and superimposed upon the first part of the diagram. To secure better intersection, curve n-n was replaced by a straight line. The points h on each line gh were shifted down to the new line and line T U was then drawn through the points g giving the curve shown on the completed diagram.


Area in Square Inches per Foot of Width.
Pounds per Square Foot
200
300
400
600
800
1000
1500
2000
2500
3000
Plotted for Values
f_s = 13500#
f_c = 750#
L=20'
L=18'
L=16'
L=14'
L=12'
L=10'
L=8'
L=6'
L=5'

THE SANTA FE INDIVIDUAL EFFORT OR BONUS SYSTEM

William L. Bean, M. E. '02

The prime object of the bonus system on the Santa Fe Railway is to induce employees to work at a high efficiency by rewarding them with cash payments for savings effected through their individual efforts.

By paying employees a fixed daily wage and then permitting them to increase their earnings by additional amounts dependent on the net results of their efforts, the workmen become partners with the company to the extent that they receive a share of the savings effected by the higher working efficiency.

Workmen are not necessarily happier or more contented when working under day labor conditions which are inefficient and wasteful, than under some semi-partnership arrangement such as the bonus system where there is an incentive to save because they receive a part of the savings.

Normal man is happier and more healthy mentally if he uses his brain in connection with his work. Without any considerable increase in physical effort most workmen can very largely increase their working efficiencies by planning their work so as to avoid waste.

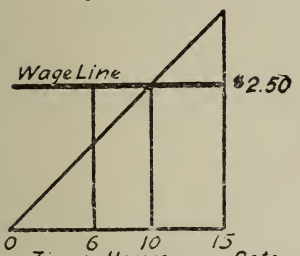
Any fair minded workman would testify that when he is accomplishing good results in his work the time passes rapidly and when for one reason or another the work drags the day is insufferably long and tiresome.

Believing day labor conditions to be unfair to employee and employer alike, the Santa Fe in November, 1904, instituted the bonus or efficiency system as a form or remuneration for individual effort, employing Mr. Harrington Emerson as Efficiency Engineer to supervise the installation.

A brief comparison of various systems of wage payment may be of interest. Accordingly several diagrams accompanied by small tabulations are presented herewith by way of illustration.

In all of these charts, the time in hours is measured by the horizontal lines, and the wages paid, in vertical lines, the difference between the heavy wage line and the hypotenuse of the right triangle indicating the increase or decrease of wages as bonus or penalties according to performance.

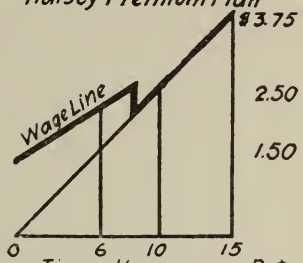
Piece Rate Plan



Time in Hours	Hrs.	Wages	Rate per Hour
Slow Time	15	$2.50	16.6¢
Fair Time	10	2.50	25 ¢
Fast Time	6	2.50	41.7¢

(Fig 1)

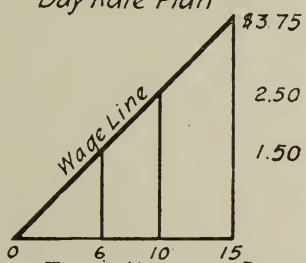
Halsey Premium Plan



Time in Hours	Hrs.	Wages	Rate per Hour
Slow Time	15	$3.75	25¢
Fair Time	10	2.50	25¢
Fast Time	6	2.00	33.3¢

(Fig. 2)

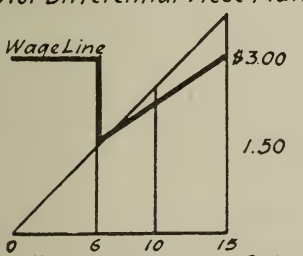
Day Rate Plan



Time in Hours	Hrs	Wages	Rate per Hour
Slow Time	15	$3.75	25¢
Fair Time	10	2.50	25¢
Fast Time	6	1.50	25¢

(Fig. 3)

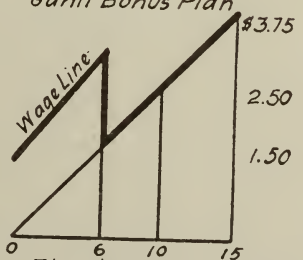
Taylor Differential Piece Plan



Time in Hours	Hrs	Wages	Rate per Hour
Slow Time	15	$3.00	20¢
Fair Time	10	2.15	21.5¢
Fast Time	6	3.00	50¢

(Fig. 4)

Gantt Bonus Plan



Time in Hours	Hrs	Wages	Rate per Hour
Slow Time	15	$3.75	25¢
Fair Time	10	2.50	25¢
Fast Time	6	3.00	50¢

(Fig. 5)

In all of the charts it has been assumed that an operation can be performed in a satisfactory manner by an average workman, in 10 hours, by a poor workman in 15 hours, and by a fast workman in 6 hours, the rate per hour being 25 cents in all cases.

Under the day rate system (see Fig. 3) the Company makes all the gain and suffers all the loss through variation in time, the 15-hour job costing $3.75, the 10-hour $2.50, and the 6-hour $1.50; the employe deriving no benefit from the extra effort necessary toward reduction in time.

Under this system the general tendency is toward deterioration, since extra effort is so hard to secure unless a substantial reward is forthcoming, the personality of the foreman being the only means of inducing co-operation.

In the piece-rate plan (see Fig. 1) the employee is paid a a stated sum for a certain piece of work regardless of the length of time consumed. In this case the employee makes all the gain and suffers all the loss resulting from variation in time, which latter feature often works a hardship on the employee, since he is often penalized for something over which he has no control, viz., lack of power, failure of tools, broken belts, etc.

In order to remove some of the unsatisfactory and unjust features of the piece-rate system without departing from the principle of rewarding special effort on the part of the workman, many plans have been devised, including the Taylor Differential Piece Rate (see Fig. 4), the Halsey Premium (see Fig. 2), the Gantt Bonus (see Fig. 5) and the Santa Fe Efficiency Plan (see Fig. 6).

With the Taylor and Gantt systems, only the exceptionally fast workman will profit, the former paying a large bonus for going under standard time and penalizing the workman 25% of his regular rate for failure to reach it, while the latter system does not pay as large a bonus, but does not impose a penalty for failure to reach standard.

With the Halsey plan standard time is set for the average man, but the premium equal to one-half the time saved, does not begin immediately, so that only the fairly fast men are able to profit.

With the efficiency plan the standard is set, not at a time that only the exceptional workman can attain, but at a time that the work can be done by the average man and at this time 20% of the wages is paid as bonus. If a man does better than standard time he is not only paid 20% of his wages,

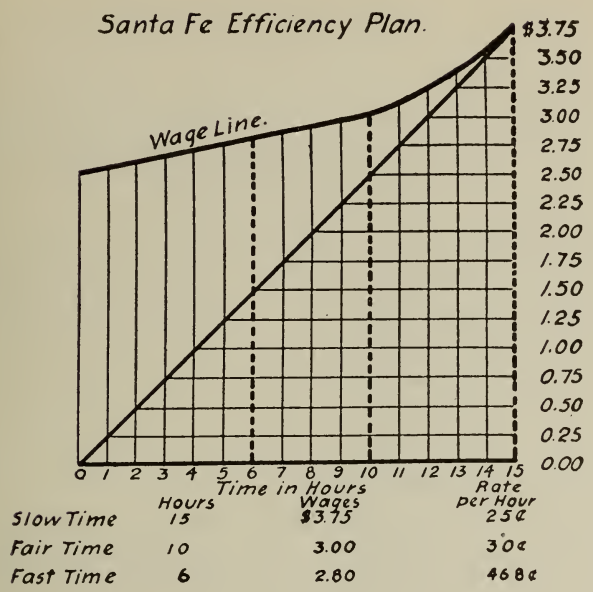


Figure 6

as bonus, but is paid in addition a bonus equal to all of the additional time he saves after attaining the Standard.

If he does not reach standard time he suffers no penalty, but is paid bonus according to the curve until the time consumed equals 50% more than standard, and receiving his regular wages should the time consumed be in excess of the 50% limit.

Within a standard, scientifically determined, the workman is not only entitled to a reward for attaining that standard, but should be paid, not one-third, or one-half, but all of the time he saves below that standard, for it is to be remembered that the wage cost of labor is only one of the total costs of doing business, even if the employer gives the workman all his savings, the business gets the entire benefit of the saving in overhead expenses attendant on the increased output of the shop.

A square deal must be given the employee in order to enlist his entire cooperation and no penalty should be imposed for conditions beyond his control, neither should any restrictions be placed on his earning capacity if reduction of time is a result of his own efforts.

The application of a little common sense coupled with a little knowledge of human-nature is a very effective stimulant in securing the co-operation of a workman, and failures are often due to the lack of these items.

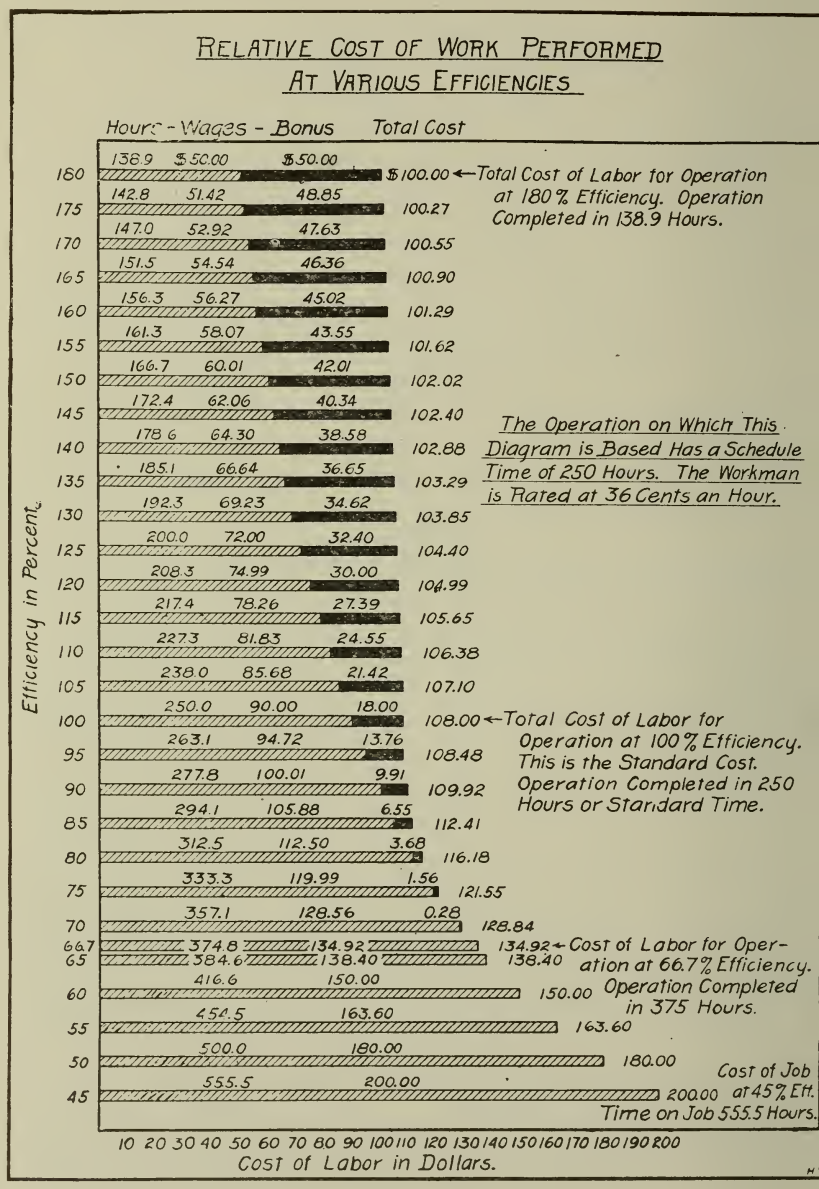

RELATIVE COST OF WORK PERFORMED
AT VARIOUS EFFICIENCIES
Hours - Wages - Bonus Total Cost
Efficiency in Percent.
180 138.9 $50.00 $50.00 $100.00 ←Total Cost of Labor for Operation at 180% Efficiency. Operation Completed in 138.9 Hours.
175 142.8 51.42 48.85 100.27
170 147.0 52.92 47.63 100.55
165 151.5 54.54 46.36 100.90
160 156.3 56.27 45.02 101.29
155 161.3 58.07 43.55 101.62
150 166.7 60.01 42.01 102.02
145 172.4 62.06 40.34 102.40
140 178.6 64.30 38.58 102.88 The Operation on Which This Diagram is Based Has a Schedule Time of 250 Hours. The Workman is Rated at 36 Cents an Hour.
135 185.1 66.64 36.65 103.29
130 192.3 69.23 34.62 103.85
125 200.0 72.00 32.40 104.40
120 208.3 74.99 30.00 104.99
115 217.4 78.26 27.39 105.65
110 227.3 81.83 24.55 106.38
105 238.0 85.68 21.42 107.10
100 250.0 90.00 18.00 108.00 ←Total Cost of Labor for Operation at 100% Efficiency. This is the Standard Cost. Operation Completed in 250 Hours or Standard Time.
95 263.1 94.72 13.76 108.48
90 277.8 100.01 9.91 109.92
85 294.1 105.88 6.55 112.41
80 312.5 112.50 3.68 116.18
75 333.3 119.99 1.56 121.55
70 357.1 128.56 0.28 128.84
66.7 374.8 134.92 134.92 ←Cost of Labor for Operation at 66.7% Efficiency. Operation Completed in 375 Hours.
65 384.6 138.40 138.40
60 416.6 150.00 150.00
55 454.5 163.60 163.60
50 500.0 180.00 180.00
45 555.5 200.00 200.00 Cost of Job at 45% Eff. Time on Job 555.5 Hours.
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Cost of Labor in Dollars.

Figure 7

If a standard time is set so that only a small percentage of the men can reach the standard, and no remuneration given until that standard is reached, those failing to receive compensation will lose interest after several attempts, and gradually drift back to the day-rate plan and give sufficient return to permit to be kept on the pay-roll.

The rate of increase of bonus earnings to the workman and of saving to the employer as the time rate of an operation decreases is clearly shown by Figure 7.

A copy of a practical form of Santa Fe bonus schedule is given below to illustrate the method of application of the bonus principles to direct operations. The shedule selected covers the activities of a locomotive supplyman.

That the efficiency of the workmen has been raised in the Santa Fe shops due to the stimulus of bonus, is reflected by the fact that the actual average efficiency of the mechanical department in December 1910 was 88.8% and that 87.2% of all operations were covered by bonus schedules. This efficiency gave an average cash bonus of $9.03 to the workmen, or 9.11% of their wages.

It should not be overlooked that average figures are given and that it is not unusal for skilled mechanics of long experience to make as high as 120% efficiency and to increase their wages from $40.00 to $50.00 per month.

These figures indicate that the schedule standards are neither too high nor too low and that workmen can obtain a reasonable additional compensation through the exercise of individual effort, and employer and employee be mutually benefited.

No. Z2–11. Effective December 1, 1909.

LOCOMOTIVE SUPPLYMEN.

STANDARD SCHEDULE.

.....Division.

For efficiency and economy in handling, caring for, repairing and issuing small supplies and equipment carried on locomotives, and for keeping equipment complete on each locomotive as per Form 1174 Standard, and for supplying headlight and signal oil and waste to locomotives, a bonus is paid monthly to supplymen according to the division efficiency and table below.

1. Cost of supplies by divisions, accounts 76 and 85 (as reported by M. P. A. to Auditor), six months' total, divided by locomotive mileage in hundreds (per Form 1396 Standard), six months' total, gives actual cost per one hundred locomotive miles.

2. The six months' figures to be used are those for the six months ending with the current month.

3. The standard cost on this division is.....cents per one hundred locomotive miles.

4. Standard cost divided by actual cost determines per cent of efficiency for division.

5. Bonus on division efficiency is allowed for each one hundred locomotive miles as per following table:

Effic.	Bonus in cents.	Effic.	Bonus in cents.	Effic.	Bonus in cents.	Effic.	Bonus in cents.
66.7	0.000	76.0	0.420	86.0	0.870	96.0	1.320
67.0	0.015	77.0	0.465	87.0	0.915	97.0	1.365
68.0	0.060	78.0	0.510	88.0	0.960	98.0	1.410
69.0	0.105	79.0	0.555	89.0	1.005	99.0	1.455
70.0	0.150	80.0	0.600	90.0	1.050	100.0	1.500
71.0	0.195	81.0	0.645	91.0	1.095	101.0	1.545
72.0	0.240	82.0	0.690	92.0	1.140	102.0	1.590
73.0	0.285	83.0	0.735	93.0	1.185	103.0	1.635
74.0	0.330	84.0	0.780	94.0	1.230	104.0	1.680
75.0	0.375	85.0	0.825	95.0	1.275	105.0	1.725

6. Division bonus earned on this schedule is apportioned between stations on this division as follows:

Station.....Per cent.....To Chief.....To Ass't .....
" ..... " ..... " ..... " .....
" ..... " ..... " ..... " .....
" ..... " ..... " ..... " .....
" ..... " ..... " ..... " .....

Bonus to assistant supplymen to be divided in proportion to their wages.

7. Bonus earnings to be computed monthly in office of Betterment Recorder, and included in pay-check for the month following that for which they are earned.

Supersedes Schedule No. Z2–1.

Checked by: Approved by:

....
Bonus Supervisor. *Mechanical Superintendent.*

....
Master Mechanic. *Ass't Sup't Motive Power.*

THE JOHN D. WEBBER FIELD HOUSE

I. Kvitrud, C. E. '11

It is often remarked that the beauties of valuable gems are greatly enhanced by proper settings. It is likewise very true that the John D. Webber Field House owes very much of its attractiveness to its location. It is situated on a loop of Shingle Creek as it winds through Camden Park, a twenty-one-and-a-half acre tract of land bounded by Lyndale, Washington and 44th Avenue and the "Soo" tracks in North Minneapolis. The winding creek, gently rolling grounds and numerous groves of trees give the park those natural features which, when properly utilized, makes it an ideal location for the Field House.

The John D. Webber Field House is the generous gift of Mr. and Mrs. John D. Webber, of Minneapolis; at present it is divided into three parts, known by the following names:-

1. The John D. Webber Field House—for shelter.
2. The Camden Park Swimming Pools.
3. The Camden Park Library.

Perhaps the most interesting parts of this are the swimming pools and the dressing room accomodations. From a glance at Figure 1 it will be seen that there are two pools, which are entirely open to the elements and are furnished with water from Camden Lake. To the north are the dressing rooms and to the south is the shelter.

Camden Lake is formed by a dam thrown across Shingle Creek at the southwest corner of the pools and by a retaining wall at right angles to the dam at the west end of the pools. The dam is substantially built of reinforced concrete, is approximately forty feet long, and is divided into two overflows, each eleven feet long. The crest is eight feet above the bed of the stream and four inches below the sill of the spillway at the entrance to the pools. A fishway is provided at the west end; and at the other extremity are two 24″ outlet pipes controlled by gates. The water surface is raised, during the filling of the pools, by inserting boards in groves which are provided above the crest. The incompleted fishway and the tops of the outlet pipes can be seen in the accompanying cut of the dam.

Water overflowing from the lake first enters what is known as the shallow pool (Figure 2) This is 60x120 feet, with a

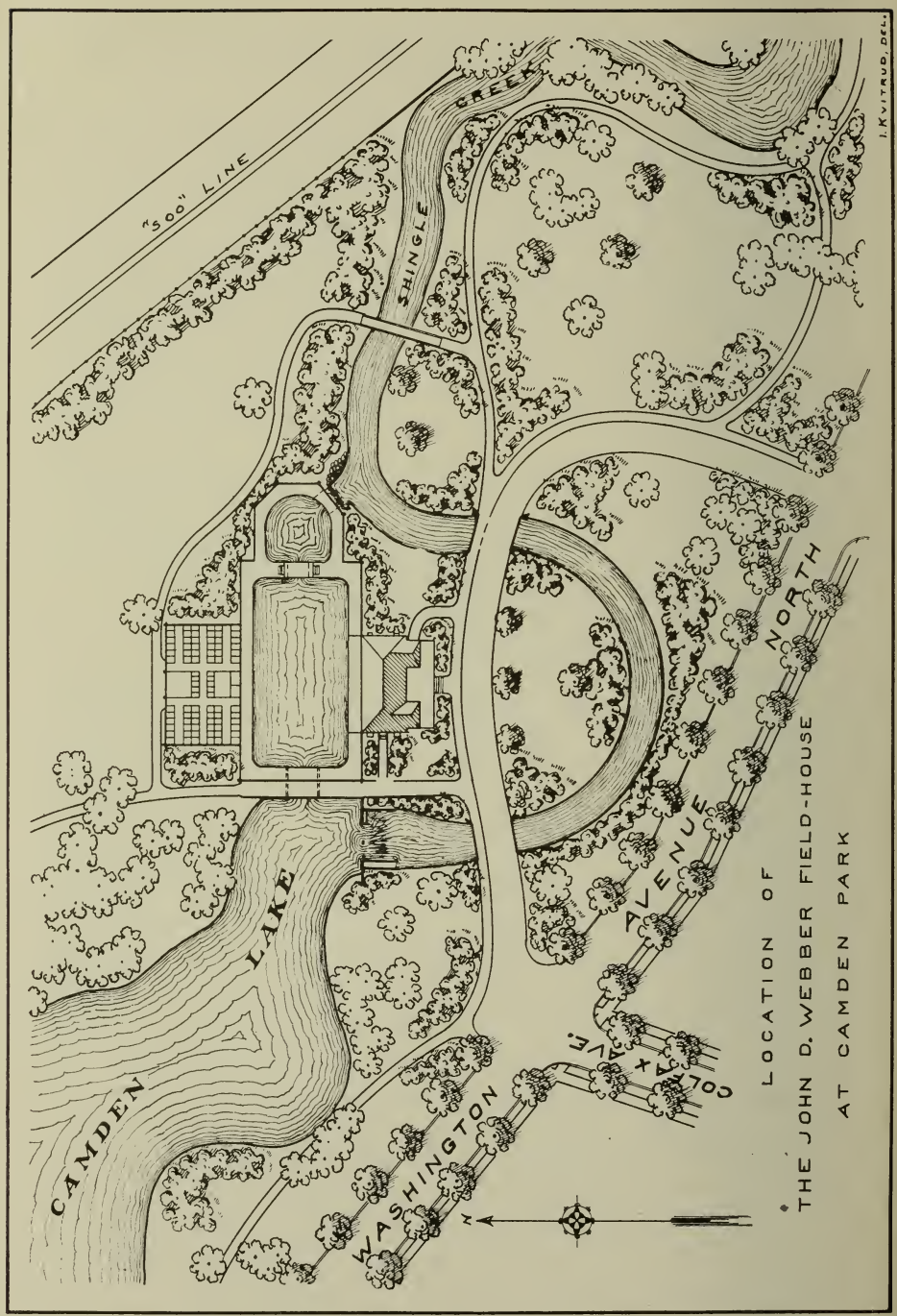

"500" LINE
SHINGLE CREEK
CAMDEN LAKE
WASHINGTON AVE.
COLFAX AVE.
3RD AVENUE NORTH
LOCATION OF
THE JOHN D. WEBBER FIELD-HOUSE
AT CAMDEN PARK
N
I. KVITRUD, DEL.

Figure 1

depth of water varying from 3 feet at the west end to 4 feet at the east end. At this end is the deep pool, 43x45 feet and with 9 feet of water. Water passes between the pools through a bridge built over the platform between. From the deep pool it flows through a large outlet in the wall, over a concrete shelf and into the creek, about nine feet below. The depth of water in both pools may be increased about 9 inches. The water can be drawn off through the drains in two hours, and the pools filled in one hour.

Plain and reinforced concrete construction is used throughout, except where wood is required for inside finishing or for architectural embellishment. The walls of the pools are 12 inches thick at the top, increasing to 16 and 18 inches at the bottom of the shallow and deep pools respectively. The floor systems are uniformly 6 inches thick. The walls and doors are reinforced with a 6 inch mesh of No. 9 (about 15/100 inch diameter) high carbon steel, principally for the purpose of tieing together the concrete and to prevent temperature cracks. To further provide for temperature changes 3 inch asphaltum expansion joints are placed in walls and floors as indicated in Figures 2 and 3. Anchored to the walls at a distance of 5 inches below their top, and 5 inches above the water, are 1½ inch gas pipe railings. Cement steps are provided in the shallow pool, and ladders in the deep one.

A 9 foot platform almost surrounds the large basin and a 6 foot walk extends around the deep pool except between pools, where the platform is 11 feet wide. The usual transverse reinforcing consists of ½ inch rods spaced 12 inches. All platforms slope 2 inches toward the inside and are uncovered, except for the portion adjacent to the shelter. Inclosing pools and platforms is a 10 foot buttressed rough cast concrete wall with smooth coping. Electric lights are bracketted from the wall as shown in figures, but at the present time there are nearly twice as many as indicated.

Two doors in the north wall open into uncovered passageways leading to the dressing rooms, shower baths, attendants' office and toilets. There are 82 double size dressing rooms, 3′—6″×5′—0″, having concrete floors, walls and roofs. The walls and roofs are 2 inches thick, reinforced with expanded metal lath and 1½ inch channels spaced 15 inches. The frames of the doors are composed of 2 inch channels. Wire mesh vents are placed above doors and in the walls separating two rows of rooms. Seats are attached to angles extending through the back wall and bolted to the side walls. The passageways

Figure 2

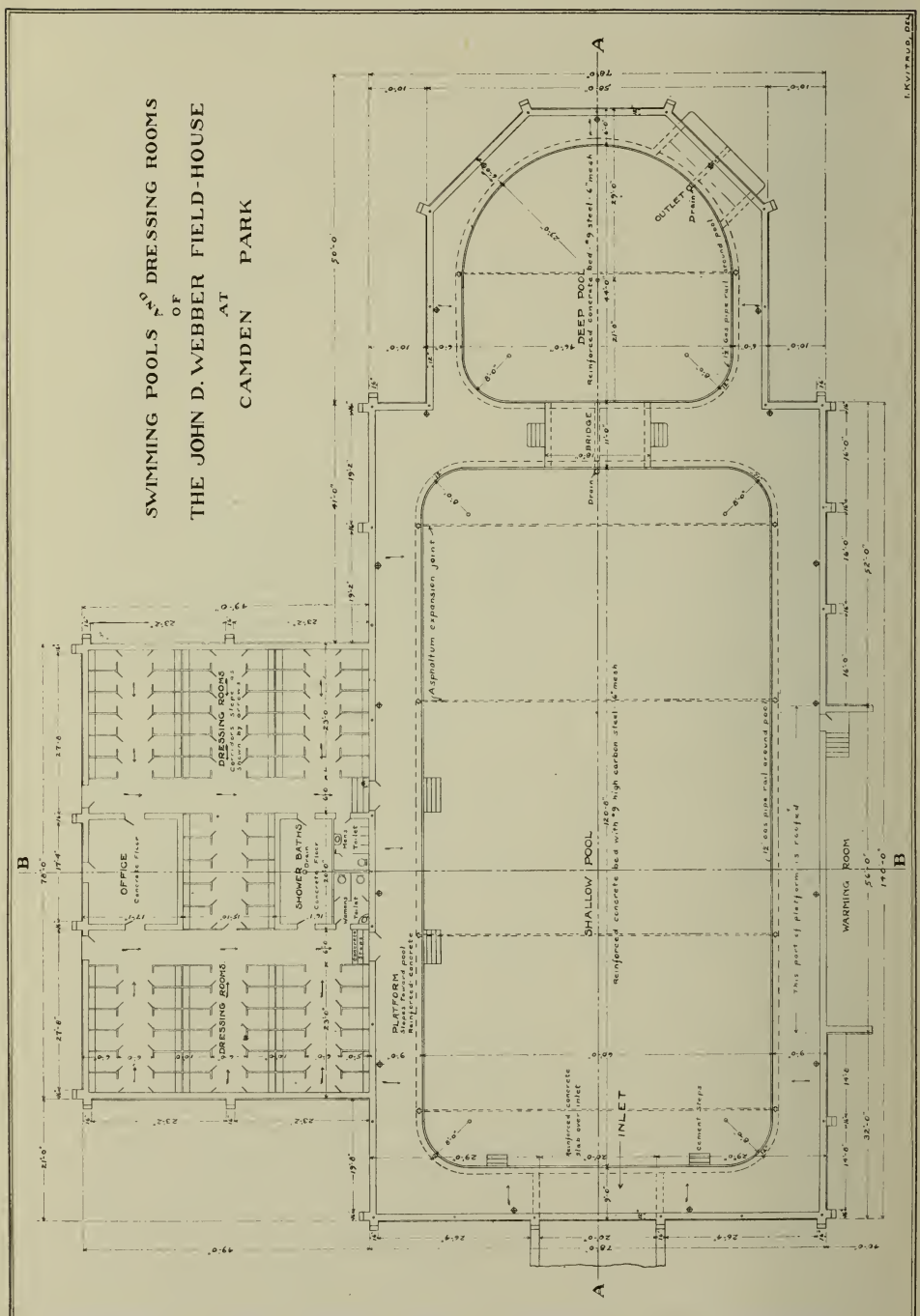
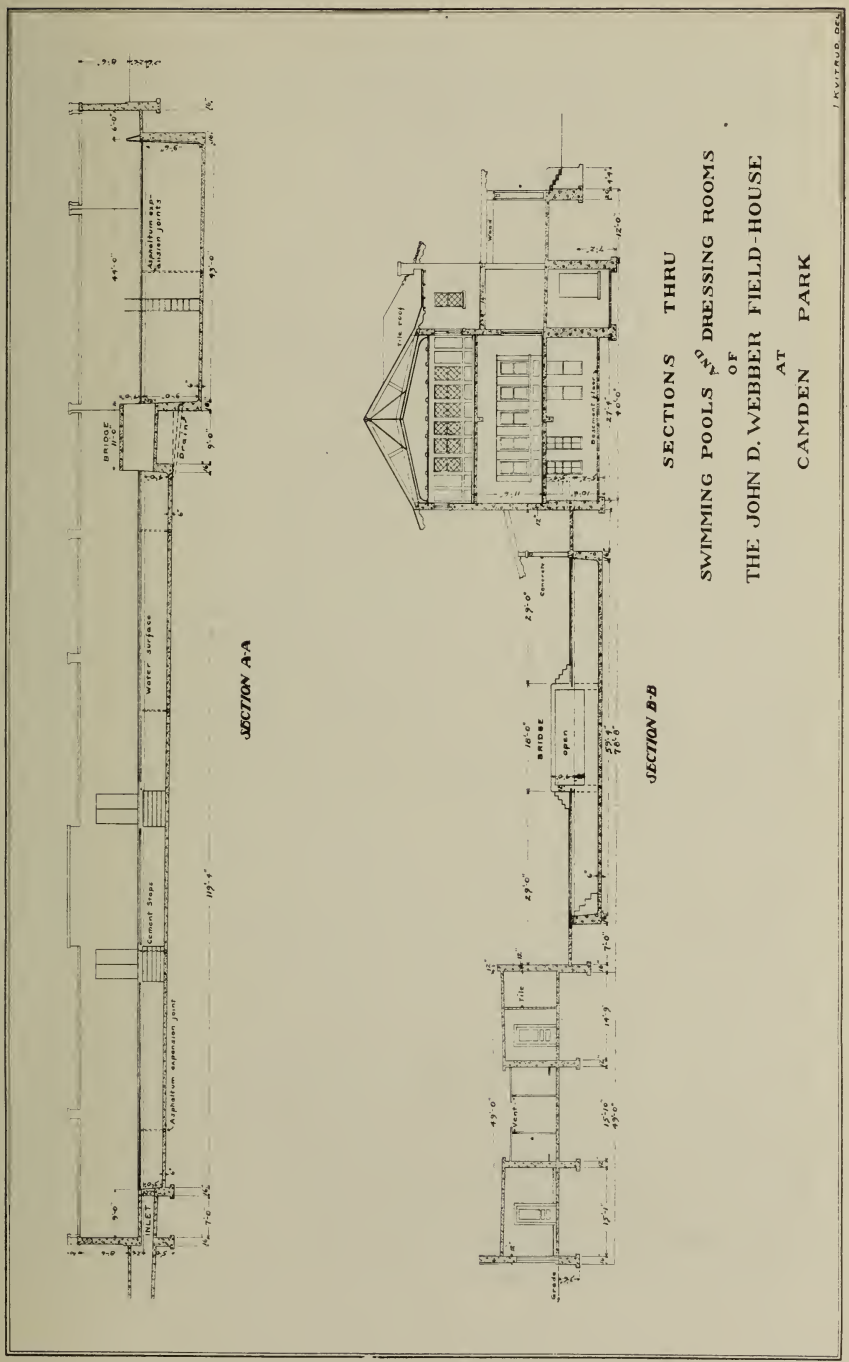

SWIMMING POOLS AND DRESSING ROOMS
OF
THE JOHN D. WEBBER FIELD-HOUSE
AT
CAMDEN PARK
DEEP POOL
SHALLOW POOL
DRESSING ROOMS
OFFICE
SHOWER BATHING
PLATFORM
WARMING ROOM
INLET
OUTLET
BRIDGE
A
B

Figure 3


SECTION A-A
SECTION B-B
SECTIONS THRU
SWIMMING POOLS AND DRESSING ROOMS
OF
THE JOHN D. WEBBER FIELD-HOUSE
AT
CAMDEN PARK

are sloped in the directions indicated by the arrows in Figure 2.

South of the pools is located the main building, a cross sectional view and cut of which are shown. (Figure 3). The first floor is 27x53 feet, and is used as a shelter in summer and as a warming room during the skating season. Booths for checking clothes and skates and toilet rooms are located here. The second floor is occupied by the Camden Park Library, a branch of the public library. In the basement are the boiler, storage and unassigned rooms. The latter may eventually be equipped with shower baths for winter use.

Here also is located the equipment which furnishes drinking water to the fountains in the building and throughout the park. This consists of a 2 H. P. 220 volt 60 cycle single phase moter of 1150 r. p. m. connected to a vertical triplex power pump, 50 r. p. m. with a capacity of 18 gallons per minute. The water is pumped into a compression tank 48 inches in diameter and 16 feet long, which is placed beneath the basement floor. The water capacity of the tank is 1,000 gallons, with air in the upper third; and the working pressure is 40 pounds. The motor is equipped with a two-pole automatic starting and stopping device, worked from air pressure in the tank, so that the motor requires practically no attention. The water is obtained from an 8 inch artesian well 345 feet deep, cased to the Jordan Sandstone at a depth of 270 feet. At present the water in the well stands a few inches below the basement floor.

Lack of space forbids a detailed treatment of the dam and retaining walls, or a discussion of the sewerage disposal system. A study of the accompanying sketches and cuts, together with the information furnished this article, may perhaps enable the reader to form some opinion concerning this useful and noble gift.

The architects for the John D. Webber Field House were Long, Lamoreaux and Long, of Minneapolis. The contract for the construction was let to J. & W. A. Elliot Co., contractors and builders, who commenced in the spring and finished in the fall of 1909. The dam and retaining walls were designed by, and constructed under the direction of A. C. Godward, Engineer with the Park Board.

The writer wishes to give due credit to the architects' plans from which the accompanying sketches were made, and to thank the Board of Park Commissioners for their courtesy in allowing the use of the several cuts included.

Camden Park Dam

John D. Webber Field House.

TESTING BRIDGE STRINGERS AT THE GOVERNMENT TESTING STATION SEATTLE, WASH.

Paul S. Buhl, M. E. '07

The purpose of making timber tests is to determine the moduli for design, also to compare the strength values of different species of structural timbers.

The trees are selected in the forest by a representative from the timber testing station. He marks the butt and top end of each 32 foot log cut from a tree. He also marks the log so that its relative position in the tree will be known. The logs are next sawed and surfaced at a mill. When finished, they measure approximately 8″x16″x16′. The beams thus prepared, numbering about sixty, are closely piled on a car and sent to the testing station. Upon arrival they are graded as follows: clear, merchantable and common. When possible, an equal number of tests of each grade are made, so that the strength of the different grades may be compared. Next each grade is divided into two lots. One to be tested green, the other to be air dried. It takes from two to three years to air dry beams. The beams which are to be tested green are closely piled and covered with planks which are kept moist, to prevent surface drying. Beams, which are to be air dried, are piled in the drying shed so that air freely circulates around each beam.

Each beam is given a number at the timber testing station, and the history of each beam is kept on file, so that after a great many tests have been made, the strength of the logs from different cuts of the same tree may be compared. The strength of timber of the same species from different parts of the state, and from different parts of other states are compared also.

Tests are made to determine the effect knots have on timbers. This is done by testing clear beams, beams with knots on top side only, bottom side only, and knots on both sides.

A beam is weighed and measured along four edges to obtain its average length. The average height and width are obtained by taking measurements at the center and at points thirty inches on each side of the center. The four sides of the beam are next sketched, showing all defects such as knots, pitch pockets, wanes, wind shakes, checks and irregular grain.

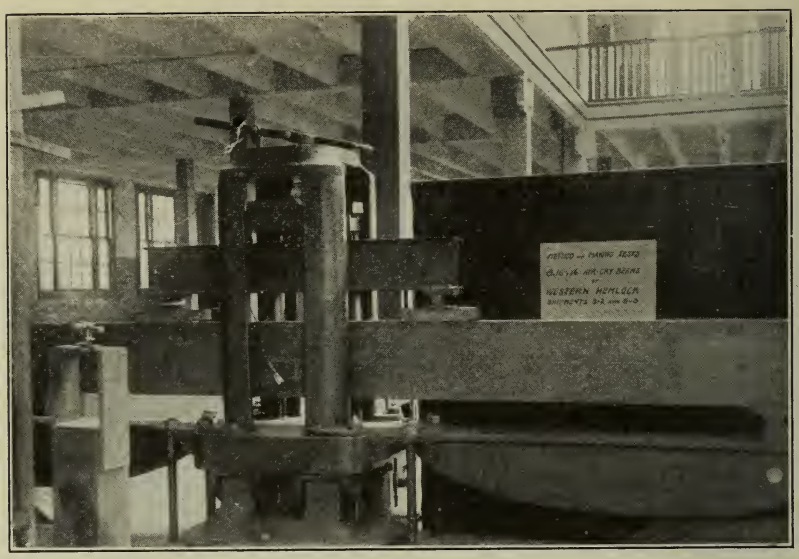


Figure 1.—Beam in Place for Testing

Sketches of the ends of the beam, showing the direction of the grain and possibly locating the heart, are made. Now the beam is tested in Olsen's 200,000 pound testing machine, on a 180″ span. The load is applied at the third point, that is at two points on the beam five feet from the points of support and five feet between load points. (See Figure 1).

By using third point loading, the test approaches more nearly the practical condition. Under third point loading any weakness in the middle third of the beam will develop, because the stress is the same for the whole middle third, while in center loading the weakness in the middle third of the beam may not develop, as the stress is the greatest at the center. 'By referring to the cut (figure I) you may see how the pressure is applied. The head bears down upon a fulcrum, which in turn rests upon a plate fastened to two I-beams by counter-sunk rivets. The I-beam transmits the pressure to two rollers about 2″ in diameter which are placed exactly thirty inches from the center of the fulcrum in the head of the machine. The rollers rest on bearing blocks. The bearing blocks are slightly rounded and of sufficient size to prevent local crushing of the beam. . The supporting fulcrums are of the rocker type. Here also a bearing plate must be used.

The deflection of the beam is measured by means of a fine wire which is supported by nails over the rocker bearings and running the full length of the span along the neutral

axis. The wire is held taut by means of a rubber band. A scale graduated in fiftieths of an inch is nailed vertically to the center of the beam. Then by means of an engineer's transit, the deflection of the beam is obtained by sighting through the transit over the wire and reading the scale to the nearest one hundreths of an inch. This is possible because transit and wire are fixed points. The scale only moves with the beam.

A curve showing the relation between load and deflection is plotted during the test. After the test is completed the maximum load is recorded and yield points located. During the test the failures are numbered in the order in which they occur. After the test the sketches of the four sides of the beam are completed by sketching in the failures. A sketch is made showing the position of specimens taken from uninjured portions of the beam to be used for minor tests, also discs are taken for the determination of moisture.

A western hemlock beam is shown in cut (figure II). Its maximum load was 59,750 pounds. It was air dried. The failures were chalked to make them clear in photograph. Air dried beams usually fail by horizontal shear due to the checking of the beam in seasoning.

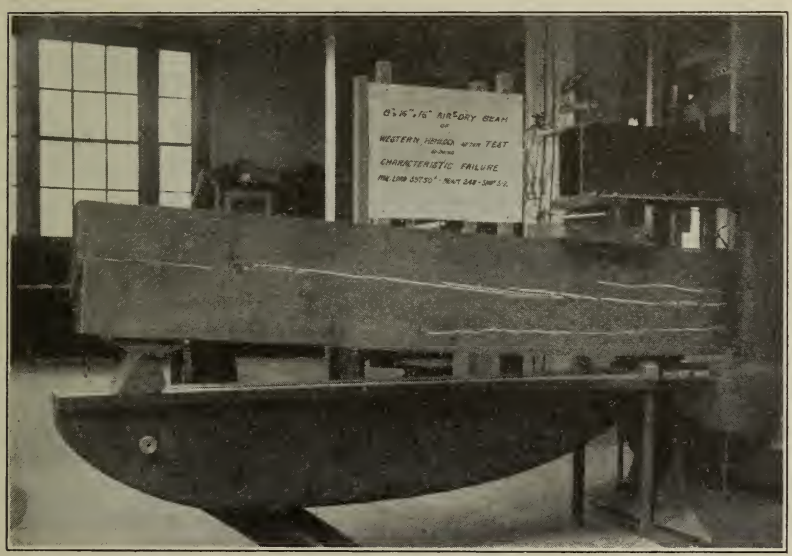


Figure II.—Beam Showing Method of Failure

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EDITORIAL

As this issue makes its appearance the University of Minnesota enters upon a new regime. President Northrop, who for over a quarter of a century has guided the institution and brought it to what it is, will on April 1st, hand over the reins to his successor, President-elect Vincent. Though "Prexy" is no longer the nominal head, his memory will always be cherished by all who knew him, and his influence will extend to students to come. But do not let us forget the successor. Let us folow up that spirit of welcome, with which the whole student body greeted Dr. Vincent in chapel, with a genuine spirit of co-operation, so that as the years go by, Minnesota may grow, and make herself felt everywhere.

The idea of a student taking and reading some technical paper is a sound one. Thus while he is still in school he can get in touch with the everyday world, and obtain material, not yet available in any text-book. In the latter he may learn all the theory and some of the general applications. Through the technical journal he will see how these theories are carried out in practical work. He may not have time to read much of the paper. The average time a student has left to himself after a certain amount has been required and

taken by the course, may not allow it. But there may be some one thing which he is interested in following up. Again the technical journals form an excellent reference library. After getting out of school, it may be very convenient to have a file of an engineering periodical to refer to on any topic. Many of the papers are offered to the students at reduced or special students' rates. The investment is a good one.

A few words in regard to the last issue of the Engineer. It was late. Material did not come in very fast. But after it did come, the printer had been handicapped by fire occurring a few weeks previous. Had it not been for that fact the issue would have been out a week and a half earlier.

The School of Mines has its building open every evening so that the students can make use of the library and drawing rooms. A Professor is in charge, and is ready to give any advice, when it is asked for. This arrangement gives a student an opportunity to look up on any subject when it is most convenient for him to do so, and also gives him a chance to do all his drafting in the drawing room, thus obviating the carrying back and forth of material or the duplication of it.

From an editorial in the February number of the "Wisconsin Engineer" on Thesis Work we have noted the following: "It is the usual experience of students starting their thesis work that they do not know how or where to begin, especially if the problem be of the nature of research work. . . . Perhaps for the first time the undergraduate finds it necessary to consult the original literature of a subject. . . . Perhaps, too, the student will first meet contradictory statements and opinions and it becomes necessary to judge for himself of the accuracy of the opinions or observations of others. The necessity for doing the work in such a way that he can safely draw correct conclusions is an additional incentive to careful and painstaking effort on the part of the student. . . . The thesis training which developes initiative, self-reliance, patience and perseverance is certainly worth while. . . ."

THE ENGINEERS' SOCIETY

W. W. Jones, E. E. '11

During the present year the following lectures and talks have been given before the Engineers' Society:

October 24, 1910, Mr. C. A. P. Turner delivered the first lecture of the school year before the society on "Re-inforced Concrete." He discussed the materials used in the concrete, their inspection, selection and suitability for the purpose. Many excellent views of concrete structural work were projected on the screen. This paper was published in the November issue of the "Minnesota Engineer."

A Student program was given on the evening of November 9, 1910. The following topics were presented: Mr. J. H. Pengilly, E. E. '11, on "Vacation Work in the Yellowstone Park;" George Manikowski discussed the working features, advantages and disadvantages of the two-cycle gas engine; J. Woodman, M. E. '11, gave a good idea of the magnitude of the plant of the U. S. Steel Corporation at Gary, Illinois. After the program refreshments were served and a general good time was enjoyed by all.

On November 30th an excellent paper was given before the society by Mr. George L. Wilson, Engineer of Maintenance of Way for the Twin City Rapid Transit Company. He discussed the various qualities of steel rails for their wearing qualities and strength to withstand excessive shocks. Several cuts were exhibited showing the microscopic structure of the steel before and after working.

Mr. W. L. Harris, past President of the Commercial Club of Minneapolis, on December 14th gave a very interesting talk to the engineers on "Business Engineering." He pointed out how there were engineering methods used in the everyday business. The history of how the ornamental street lighting system was started and maintained was given and the great benefits the merchants as well as the city derived by them.

February 15th, 1911, a students' program was given consisting of the following: C. F. Meyers, C. E. '10, gave an interesting account of the construction of the foundation for the Butler Bros. Building in St. Paul, dwelling especially on the Raymond Concrete Pile, and the method of driving. Cost

data for the pile were also submitted. C. K. Moore related some of his observations while en route through the factory of the Packard Motor Car Co. of Detroit, Mich. R. J. O'Brien, E. E. '11, gave a talk on the ballasting of track and the method of locating good gravel pits. In closing he presented a couple of problems in field geometry, one of which grew out of the transitman's forgetfulness in not bringing his fieldbook along.

An exceedingly interesting paper was read by Mr. C. H. Chalmers, E. E. '94, on "Aeronautics" on March 21st. The paper treated the various successful and unsuccessful flights of heavier-than-air machines. A review of the history of flying machines leading up to the present day showed how the first principles with modifications are being used in the most modern machines. This paper can be found elsewhere in this issue of the "Engineer."

In addition to this the Society has had one Banquet, on November 18th, 1910, at which Professor W. H. Kirchner acted as toastmaster.

COLLEGE NOTES

The Minnesota Section of the American Institute of Electrical Engineers held its first 1911 meeting in Donaldsons Tea Rooms on Monday evening, March 20. Dinner was served about 7 o'clock and was followed by a long list of very good papers on engineering subjects. Mr. E. P. Burch gave a very interesting description of the first Minneapolis street railway and the early electrical work on this by Vanderpole. Mr. E. H. Scofield of the Twin City Rapid Transit Company followed with a paper on the development of the present street railway company. This paper included a description of the 1400 KW turbo-alternator recently installed by them. Mr. Gille of the Mpls. General Electric Co. presented some very interesting statistics on the growth of the electrical industry in Minneapolis. Mr. W. H. McGrath of the Mpls. G. E. Co. gave some lessons learned from the recent fire in their Main Street staiton. Mr. Goodenough, engineer of the Stone and Webster corporation, then gave an outline of the plans for the new station to be installed by the Mpls. G. E. Co. Professeor Shep ardson completed the program with an interesting talk on the growth and present conditions of the university. All the papers given were of exceptional merit and were highly interesting. The next meeting of the Institute will take up a discussion of surges in high potential lines, and various phases of telephone engineering.

On Wednesday evening March 15, Professor W. T. Ryan presented a paper on high frequency currents before a body of Juniors and Seniors gathered under the auspices of Tau Beta Pi. The surges produced by condenser discharge were discussed and the methods of producing high frequency by means of condenser discharges were given. A number of other methods of producing the high frequency were shown. Then a discussion of the principles of wireless telegraphy and telephony was presented. After the lecture, the men indulged in a social time which was materially aided by a feed of ice cream and other delicacies.

The Minnesota Electrical Association held its annual convention on March 14, 15 & 16th in the St Paul Hotel, St. Paul. A number of the Senior Electricals took advantage of this and heard some very good papers on live central station subjects. Among those presented were papers on Gas Producers, Insurance, Residence Lighting, Safety in Line Construction, Gasoline Competition, etc., Professor Shephardson had partially

prepared a paper for the convention when he was called east. He finished it while in the east and had it presented by Prof. Ryan. The paper was on the theory of alternating current motors. An elementary motor with simple windings was used with various rotors to demonstrate some of the points brought out in the paper. The paper and demonstrations brought out in a very clear manner a number of facts concerning A. C. motors which are generally surrounded by mystery.

The call of the boy nature still existant in all of us seems to have been first answered by the Senior Electricals, for a game of indoor baseball played on the dear old drill grounds seems to be a part of the regular schedule at present.

On Friday evening, March 17, Mr. Brainerd Dyer, an expert chemist, gave a very interesting lecture on carbon products and their manufacture before the Minnesota Section of the American Chemical Society.

Mr. Skiff and Mr. Doane, representatives of the National Electric Lamp Association of Cleveland were in the Electrical department on Wednesday, March 22, looking for recruits for their engineering department. A number of the Senior Electricals had ten minute talks with these men concerning positions.

An All-Junior Engineers banquet is being planned for April 21.

R. J. O'Brien has been absent from school for some time on account of an attack of the measles.

Professor Shepardson was called to Boston on March 12th on account of the death of his sister. Classes in Alternating Currents and Journal Reading were dismissed during his absence.

The Senior Class as a whole are getting out a Minnesota Song Book as a 1911 memorial. This book has been compiled by W. W. Norton, '09, who is at present an instructor in music in the Universtiy of North Dakota. The book will contain all the songs that are popular at Minnesota. It will be of especial interest to engineers because of the fact that a "fumigated" edition of the famous Senior Engineers song

will be included. The 500 mark on the subscription list was reached some time ago and the book will soon appear.

We should all be proud of the University of Minnesota, for recent statistics show that only two similar institutions in the country, Columbia and Chicago, have more students than we. Cornell has about 7500 students, Chicago about 5900, while Minnesota is third with 5641. Michigan and Harvard are fighting for fourth place, with Michigan 10 students in the lead.

On Tuesday evening, March 7, the home of Professor Shepardson was opened to the Senior Electricals. Only three of the class were absent although O'Brien was delayed by unavoidable circumstances. A "musical romance" took all thoughts away from Steinmetz and A. C. and gave the hard-worked engineers an opportunity of developing the social side of their nature. Although, as a rule, engineers are not experts in lines of work such as dressmaking, the dolls that were produced out of potatoes and tissue would far outclass the "made in Germany" variety. All the fellows unite in declaring Professor Shepardson an ideal entertainer.

The Juniors and 1912 men were entertained by Professor Shepardson on the evening of March 10. The report is that the good time could not have been excelled. We are not fully informed as to what fellows went home alone that evening but rumor has it that a little "red-owl" party was held the next morning for the only fellow in the bunch that saw his opportunity and was game.

The block testing room in the basement of the Mechanic Arts building has recently been occupied as a club room by a number of the Freshmen. It is rumored that the Sophomores are going to clean out the bunch one of these fine spring days.

The question of securing a position is the prominent thought at present in the mind of nearly every Senior. Perhaps the locations of the members of last years class might be of interest.

O. P. Anderson and A. Landeen are with the General Electric Lamp Association, Harrison, New Jersey.

O. V. Anderson, C. M. Jesperson, L. T. Johnson, E. B. Josephson and E. E. Skytte are student apprentices with the Westinghouse Company. At present Anderson and Johnson are in New York on railway work.

V. S. Beck is in the commercial department of the Minneapolis G. E. Company.

W. E. Conley and H. A. Reid are with the National Electric Lamp Association, Cleveland, Ohio.

R. E. Dalstrom, B. P. Hustad, and R. J. Sarvis are student apprentices with the Northwestern Telephone Exchange Company, Minneapolis.

W. J. Finke is instructor in Electrical Engineering at the University of Minnesota.

C. Hansen and J. W. Powles are with the Northern Heating and Electic Company, St. Paul.

H. C. Nelson is with the Minneapolis Park Board.

R. R. Phelps is a student apprentice of the St. Paul Gas Light Company.

The Junior Electricals are again coming to the front with their novel schemes. The latest is an organization known as "The Oil Can Society." This is an honorary society and membership is limited to those who have asked at least one foolish question in class. The officers are as follows:—Chief Oiler, R. C. Mathes; Assistant Oiler, L. H. Knapp; Chief Wiper, N. C. Towle; Assistant Wiper, C. K. Hillman. The organization is growing rapidly.

The Senior Engineers have put their class song into pamphlet form. This is no doubt a very good idea; but a reading of some of the verses seems very much like driving over a stony road in an old-fashioned cart. The song has secured a place in the Minnesota Song Book, about to be published as a class memorial.

On March 4th, Messrs. Parcel and McMillan and the Senior Civils took a trip to view the new arch bridge which the "Soo Line" is putting up over the St. Croix River near Somerset, Wis. A walk to Stillwater and a round through the State Prison completed the day's program.

At a meeting of the local chapter of Tau Beta Pi the following officers for the present semester were elected: President, R. J. O'Brien; Vice-President, J. Woodman; Recording Secretary, A. G. Chapman; Historian, A. H. Mittag.

The Minnesota Football schedule for next fall has been announced. It is as follows:

Ames, Sept. 30 ..... Northrop Field
South Dakota, Oct. 7 ..... Northrop Field
Nebraska, Oct. 21 ..... Northrop Field
Iowa, Oct. 28 ..... Northrop Field
Chicago, Nov. 18 ..... Northrop Field
Wisconsin, Nov. 18 ..... At Madison
Illinois, Nov. 25 ..... At Champaign

That the Sophomore Civils do not spend all their time in study is evident by the large number of their class which attended the second of a series of dances which they are giving at Thoen's Hall. Mr. and Mrs. French chaperoned the party.

Besides these dances the class has had one theatre party, and hope to have a smoker in the near future.

The basket ball quint finished its season's shedule with a victory over Chicago on the home floor, Saturday evening, March 11th. The final score was 23 to 16. The game was hard fought and was marked throughout by consistent team work and good guarding on the part of the Minnesota guards. Rosenwald and Walker played their last game with Minnesota, and were in the game from the start. Lawler was a marked man for Captain Sauer's men, but managed to get four field goals, besides making his three free throws count.

The Senior Civils spent all of Wednesday, March 23, looking over the town of Anoka, with a view of designing a sewage disposal system for the place. The visit is thus recorded in a local paper: "Professor Bythe and a dozen or more verdant college youths were in Anoka Wednesday on a junket. They returned to the Twin Cities the same evening."

The Mechanicals of the class of 1910, who are in and about the Twin Cities held a class reunion in Minneapolis on March the second. A theater party at the Shubert was followed by a sumptuous repast at the Rogers Cafe. Old times and future prospects were talked over and much news concerning the other members, who were not present, was brought forth. That spirit which was ever strong in this class was roused again and did much toward making a congenial and pleasant gathering. Those present were Comb, Du Toit, Frear, Fleming, Moyer, Olstad and Pease.

On March the ninth the Mechanicals of 1911 gave a theater party followed by a "feed" at the Kaiserhof. This shows that the class spirit, so strong among the other classes, is likewise as dominant among the Mechanicals. The affair was a success and several more are promised in the near future.

The "Red Robin" or class letter, which was was so boldly started on its eventful trip by "Billy" Atkinson of the M. E. class of 1910, has about reached its first round. It has travelled far and wide; here and there throughout the middle west, north to the Iron Ranges and east to the Adirondaks and the Pacific Coast. When last heard of it was on its way to Boston, having already assumed enormous proportions and threatening to bankrupt each consecutive recipient who is obliged to pay postage. The experiences and first impressions of the "fellows" are both amusing, interesting and instructive. The letter contains much of that spirit so dominant in this class and which it is hoped will be as strong in all succeeding classes which leave our Alma Mater.

ALUMNI NOTES

Mr. Lewis E. Ashbaugh C. E. 1900, M. Am. Soc. C. E. who has been employed as Hydraulic Engineer in the San Francisco office of J. G. White & Co. has been transfered to the London, England., office of the same company where he is to take charge of the design of a 60,000 horse power hydro-electric plant to be built near Rio Janeiro, Brazil.

Mr. Ashbaugh recently returned to this country from a trip to South America, where he made an investigation of several proposed development propositions.

John Claybourne is holding down a position as rodman in the Canal Zone.

W. E. Conley, '10, of the National Electric Lamp Association of Cleveland has recently been operated on for appendicitis.

The men in the employ of the Western Electric Company, Chicago, claim the distinction of having originated the Chicago Alumni Association. At the Chicago-Minnesota basket-ball game at Chicago, the rooting of the Alumni Association equaled that of the Chicago supporters. A banquet was held by the Association a short time ago in honor of President-elect Vincent.

Wm. C. Weeks, C. E. '94, is located at Vancouver, B. C. Mr. Weeks has invented and perfected a dredging shovel and is engaged in dredging the Vancouver harbor and selling the gravel to contractors in the ctiy.

Harry E. Gerrish, M. E. '05, and Glenn C. Morgan, a graduate of Purdue, have established a partnership with offices at 825 Plymouth Building. The new company will be agents for the American Blower Co., Monarch-Yonker Co., Diamond Power Specialty Co. and other material for heating and ventilating equipment.

H. D. Frary, M. E. '08, and M. S. '09, of the Yacht "Carnegie" expected to sail from Buenos Ayres February 8th. Mr. Frary is navigating officer, and one of the corps of magnetic observers, and also acts in the capacity of consulting

engineer when the gas-engine plant goes wrong. The Carnegie is made of bronze instead of iron. Because of this, the compass is not affected by the ship itself and errors in former observations have been discovered.

A. Bachrach, E. E. '08, is now located in San Francisco, where he represents the General Electric Co. of Schenectady, N. Y.

Frank L. Nemec, M. E. '09, is mechanical draftsman at Gatun, Canal Zone, Panama .

D. A. Allee, C. E. '02, is construction engineer with the General Electric Co. of Schenectady, N. Y.

Ralph M. Davies, M. E. '09, is with Fairbanks Morse and Co. as city salesman. He is frequently sent out into territory covered by the Minneapolis office especially on electric orders.

A. A. Sommerfeld, C. E. '09, with the Toltz Engineering Co. of St. Paul, is at the present superintending the erection of a light and power plant at Brainerd, Minn.

O. B. Nelson, C. E. '05, is employed as engineer and draftsman on the campus improvement.

Freemont Crane, C. E. '87, has changed his address to Schofield Barracks, Oahu, Hawaiian Islands, where he is superintending the construction of the new army post being built at that place, about nineteen miles from Honolulu.

Louis P. Zimmerman, Eng. '08, was on February 22nd, married to Miss Flora Marie Santerre at Cloquet, Minnesota. Mr. Zimmerman is in charge of the Cincinnati office of the Penton Publishing Company of Cleveland, representing editorially the IRON TRADE REVIEW and THE FOUNDRY, with offices at 808 Provident Bank Building. Miss Santerre had been attending the University of Washington at Seattle, Wash., up to the time of her marriage.

Frank F. Esser, C. E. '09, can now be found at 3825 Hemlock St., Indiana Harbor, Ind., Mr. Esser is in the construction department of the Universal Portland Cement Co., and was formerly located at Chicago.

R. C. Grant, E. M. '09, was initiated into the local chapter of Tau Beta Pi, February 23.

Oscar Wodrich, C. E. '08, and Helen Brown, a former student were married in this city on February 11th.

A. E. Brockway, E. E. '09, has been transferred by the Westinghouse Co. from their Chicago house to their Minneapolis office.

Glenn Hoppin, E. E. '09, and Miss Stout of Winona, Minn. were married recently. Mr. and Mrs. Hoppin passed through Minneapolis on their way to Rearden, Wash., where Mr. Hoppin is in the employ of the Washington Water Power Co.

William Busby Atkinson, M. E. '10, and Miss Thecla Jack Brockbank were married at St. Paul, Minn., December 31, 1910. Their home will be International Falls, Minn.

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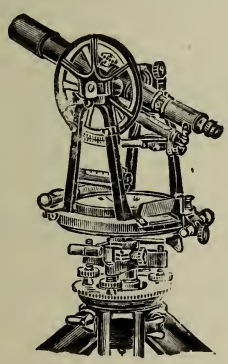

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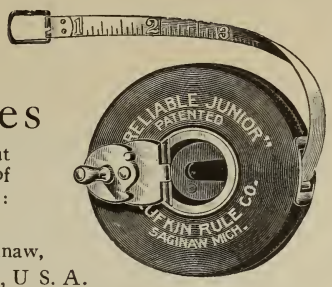

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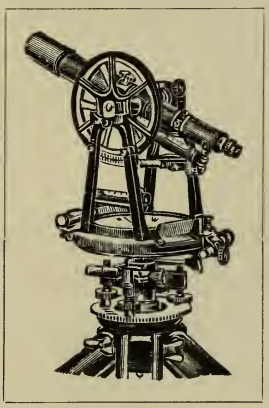

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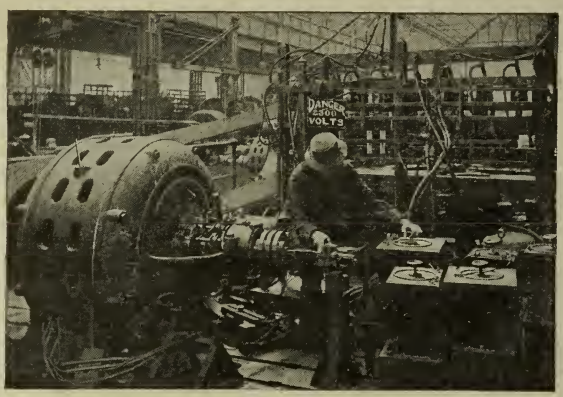

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